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## **Juno Project**

# **High-Level Mission Planning Information** (as of late October 2018)

(to be used mainly for high-level mission and science planning,  
not detailed sequencing and engineering analysis)

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Earth-Based Observers Workshop, prior to  
Division for Planetary Sciences (DPS) Conference in Knoxville  
Sunday 21 October 2018  
(with contributions from Marty Brennan and other Juno team members)



# Contents

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## **Juno latest high-level mission planning info** (as of late October 2018)

- Mission Plan overviews – DPS poster (on display Mon-Thu), IEEE paper (March 2018)
- Orbital trajectory (plots and animation)
- Global magnetic field net (plot and animation)
- Current and upcoming orbits (Orbits 15 and 16, plots and animation)
- Plots of geometry vs. perijove
- Perijove attitudes – GRAV, MWR, MWR tilt, (proposed) MWR cross-track, off-Sun
- Baseline reference trajectory (SPICE kernel or SPK file)
- Orbital data useful for science planning (8 pages, organized by PJ, mainly geometry)
- Great Red Spot predicts (tentative, based on recent observations) and animations

## **Backup**

- Nav summary of 180509 reference trajectory (6 pages)
- Terminology – Numbering for perijoves, apojooves, orbits, and sequences
- Solar conjunctions (including near AJ16 and PJ24)
- Perijove attitudes (more explanations, including 8 pages from Marty Brennan)
- Additional attitude (SPICE C-kernel) information
- Stacked linear timelines (info for all orbits on 1 page, 13 pages from Marty Brennan)
- Maneuver strategy
- Eclipse geometry and eclipse avoidance strategy
- Radiation accumulation vs. perijove (from Nav), and orbital radiation environment



# Mission Plan overviews – DPS poster (on display Mon-Thu), IEEE paper (March 2018)

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- On display this week, Monday-Thursday – **DPS poster:**
  - Including dedicated poster session: Giant Planet Atmospheres, 3:35-6:05 pm Tue 10/23.
  - I will present a poster (co-authored with Marty Brennan) illustrating the current Juno Mission Plan. It includes many of the graphical products we use to describe our orbital mission (some of which are included here).
- Presented at IEEE Aerospace Conference in March 2018 – **Mission Plan paper:**
  - At the annual IEEE Aerospace Conference earlier this year, I presented a paper that describes our current Mission Plan with 53-day orbits and how it evolved (from the 2005 New Frontiers Concept Study Report through pre-launch development and recent iterations during flight ops).
  - The paper is available online (at <https://doi.org/10.1109/AERO.2018.8396456>).
- For references to Juno science papers, see list at Magnetospheres of the Outer Planets web site (<http://lasp.colorado.edu/home/mop/bibliographies/juno-science-papers/>).



# Mission trajectory plots [1/2]

## Jupiter North Pole view, Sun direction fixed

Blue = Orbits 1 & 3-5 (yields initial 90-deg spacing)

Brown = Orbits 6-9 (45-deg spacing)

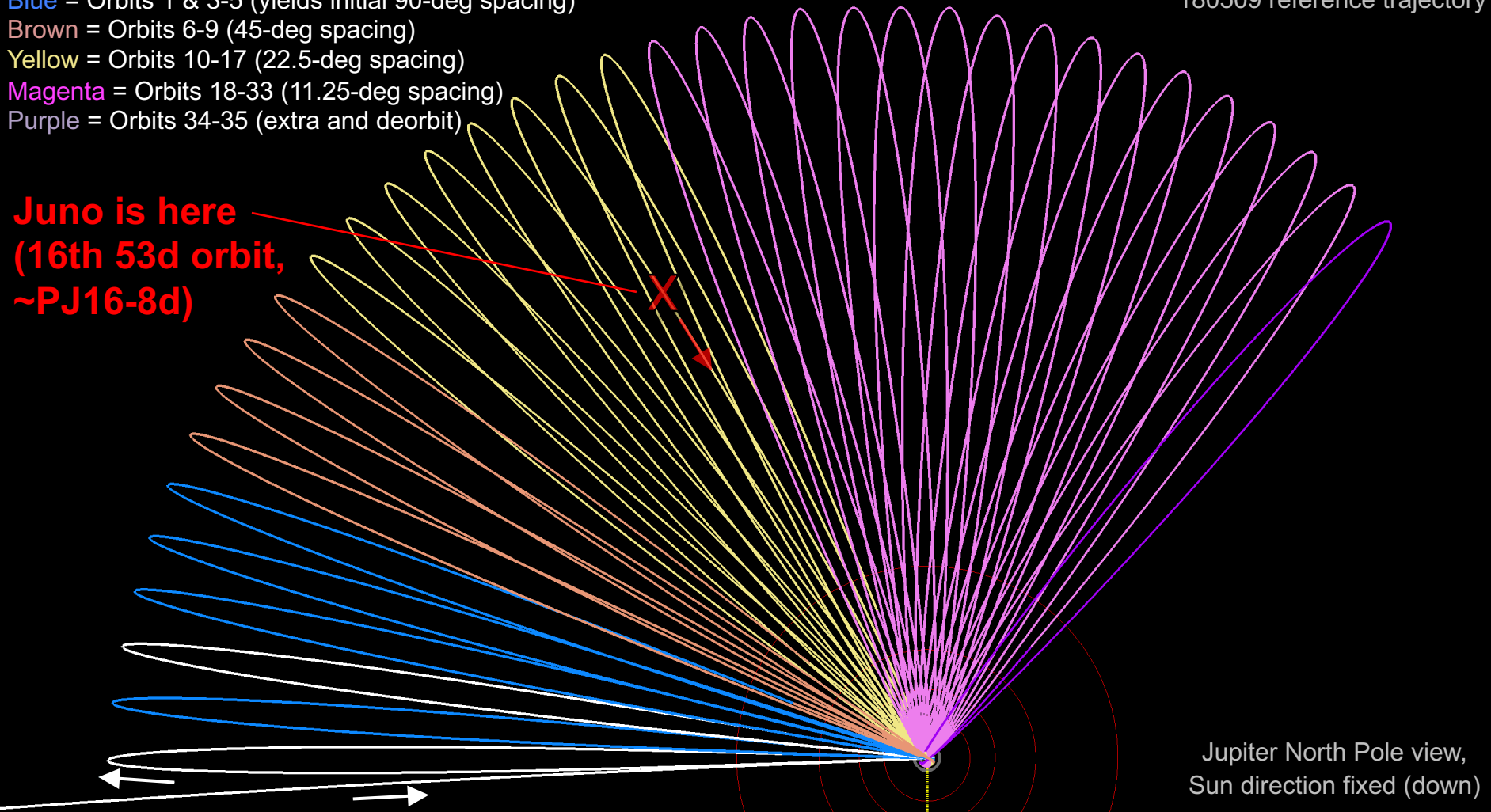
Yellow = Orbits 10-17 (22.5-deg spacing)

Magenta = Orbits 18-33 (11.25-deg spacing)

Purple = Orbits 34-35 (extra and deorbit)

180509 reference trajectory

**Juno is here  
(16th 53d orbit,  
~PJ16-8d)**



# Mission trajectory plots [2/2]

## View from Sun

180509 reference trajectory

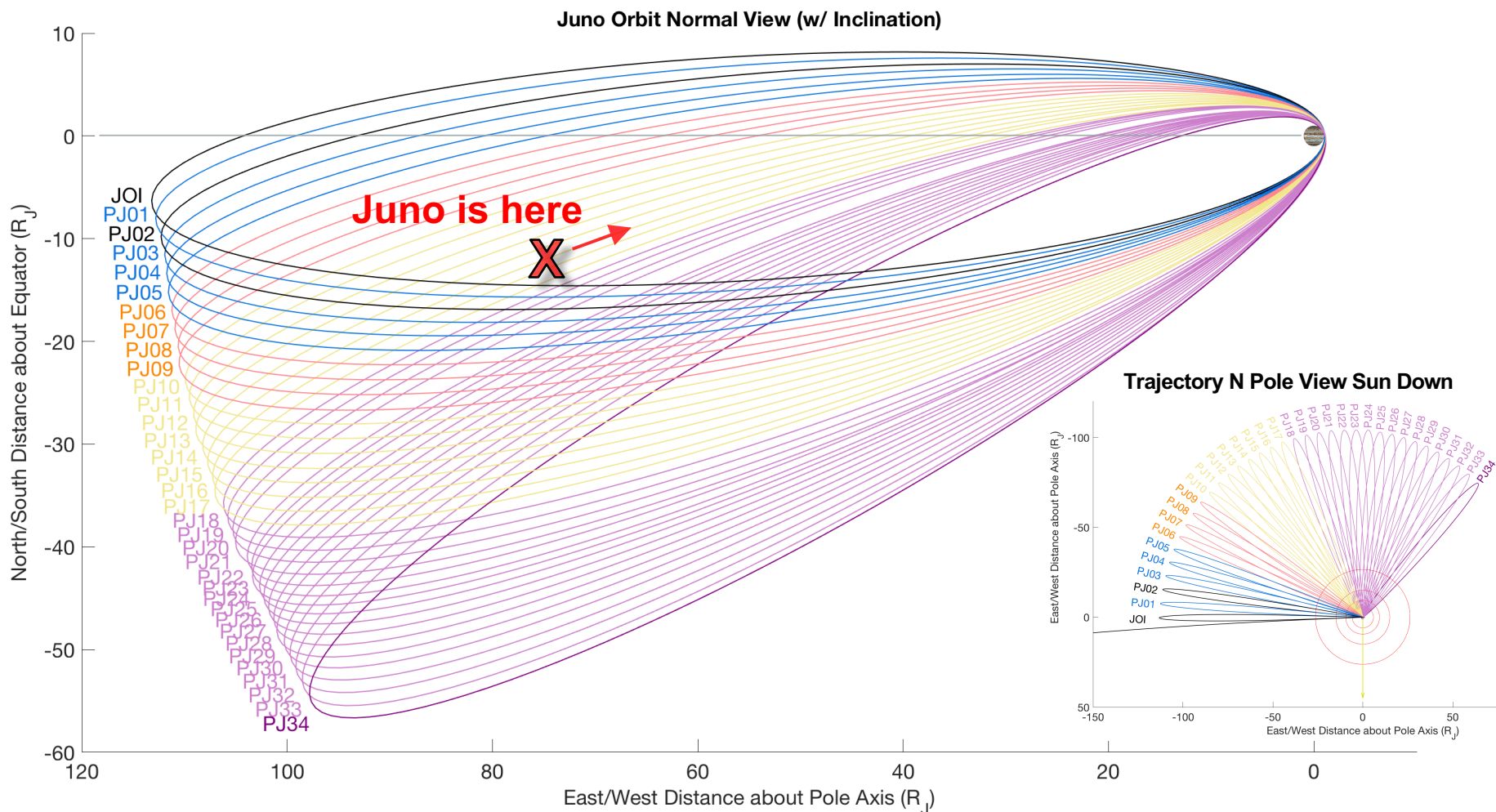
**Juno is here  
(16th 53d orbit,  
~PJ16-8d)**

Blue = Orbits 1 & 3-5 (yields initial 90-deg spacing)  
Brown = Orbits 6-9 (45-deg spacing)  
Yellow = Orbits 10-17 (22.5-deg spacing)  
Magenta = Orbits 18-33 (11.25-deg spacing)  
Purple = Orbits 34-35 (extra and deorbit)

View from Sun

# Orbits viewed from negative orbit normal direction (but allowing for inclination)

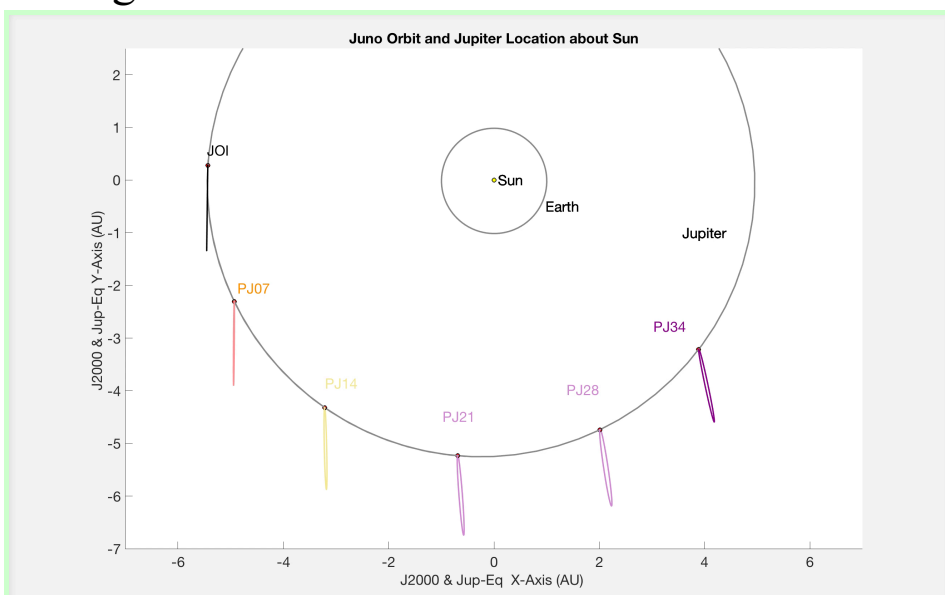
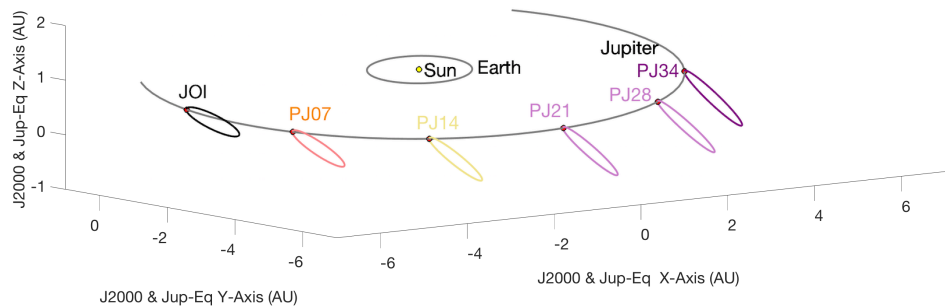
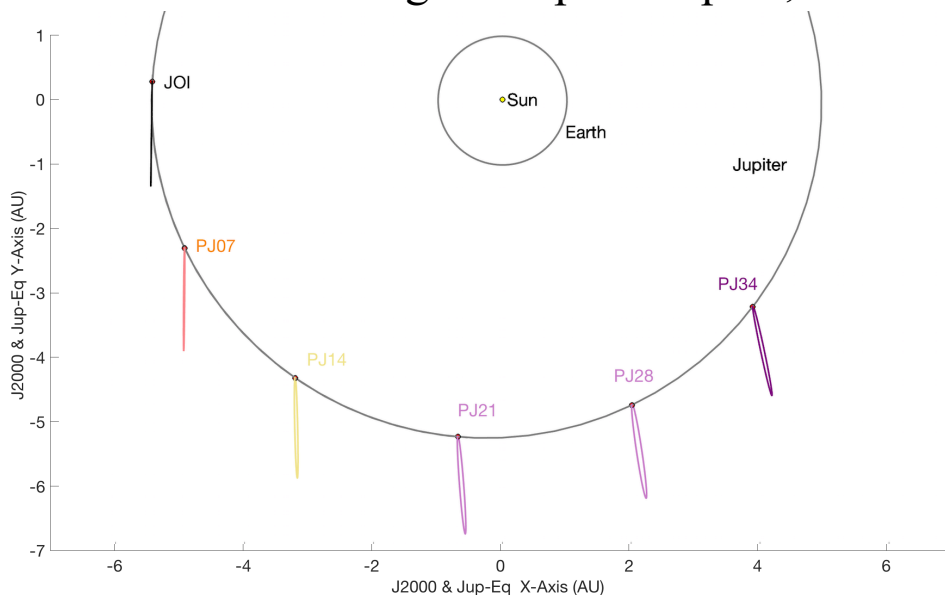
- Equator crossing ranges are accurately depicted (view is in the plane of Jupiter's equator):



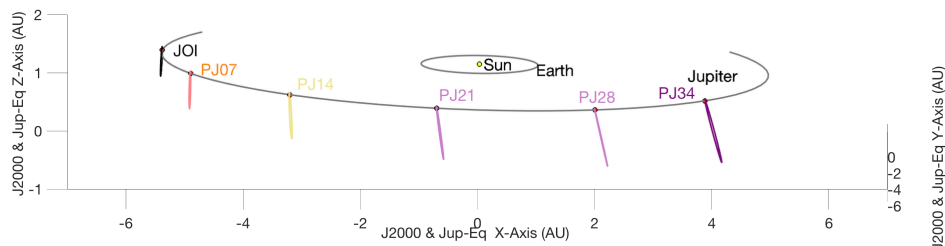
- From Marty Brennan (for 180509 reference trajectory)

# Evolution of Juno orbit as Jupiter goes around the Sun [1/2]

- Juno orbit is  $\sim 30\times$  real size – this quasi-J2000-Jupiter-Equatorial frame rotates J2000 to have +Z along the Jupiter N pole, but still having the +X axis towards the J2000 +X axis:



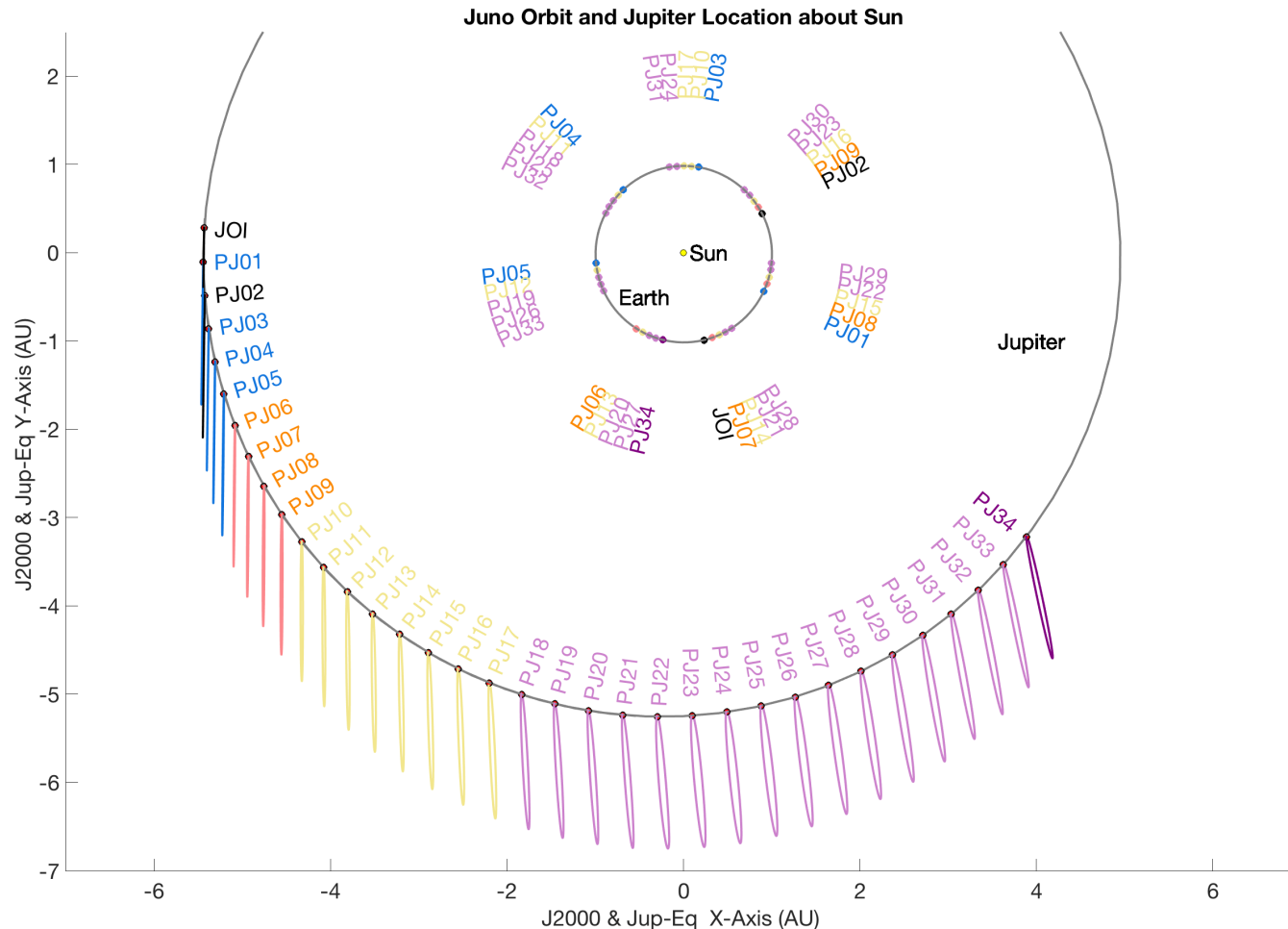
**Animation** (“play” button should appear here if you hover)



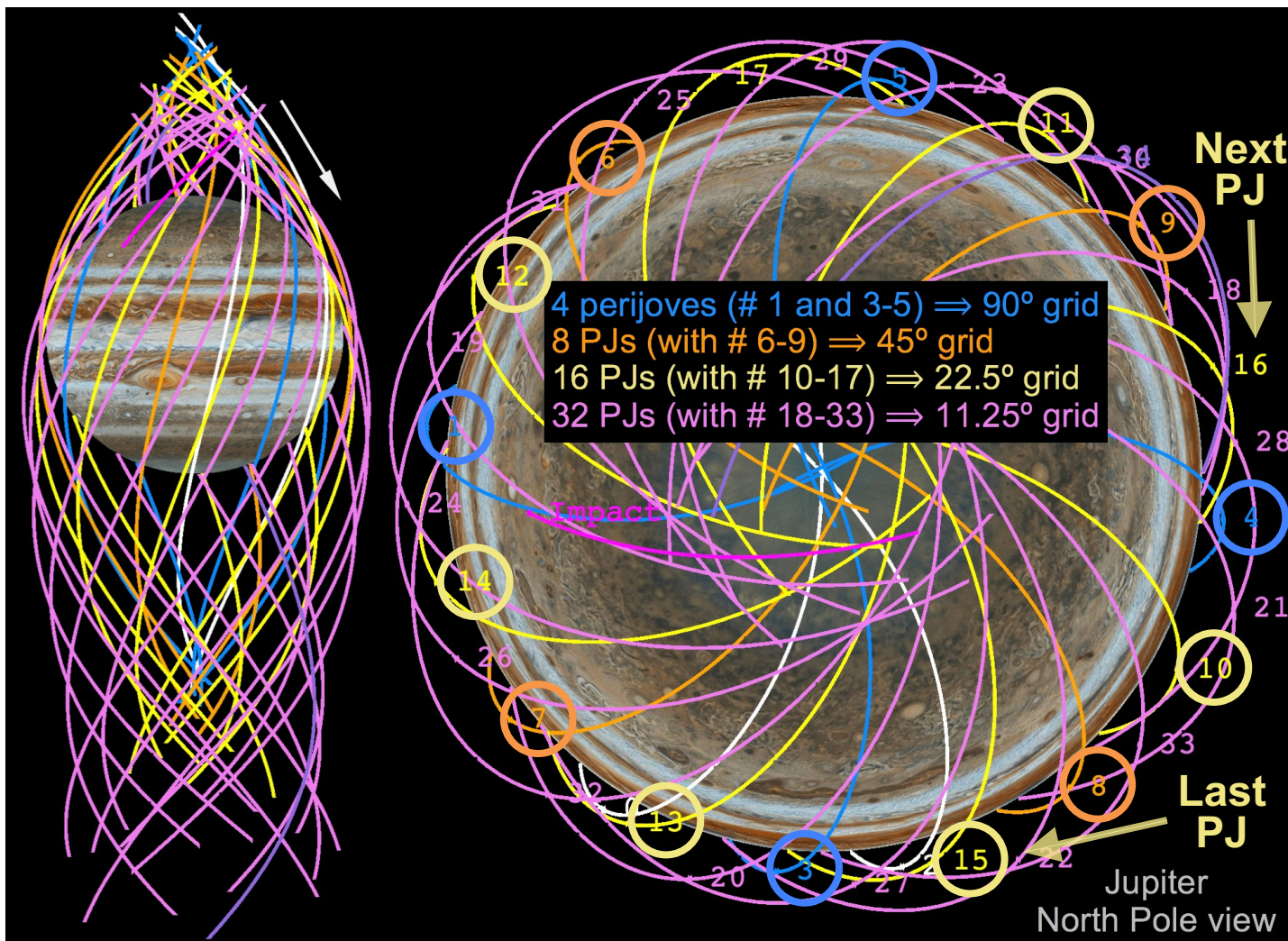
- From Marty Brennan (for 180509 reference trajectory)

# Evolution of Juno orbit as Jupiter goes around the Sun [2/2]

- Also from Marty Brennan (for 180509 reference trajectory) – this is motivated by Fran Bagenal's request involving looking at solar wind interaction with Jupiter and Earth:



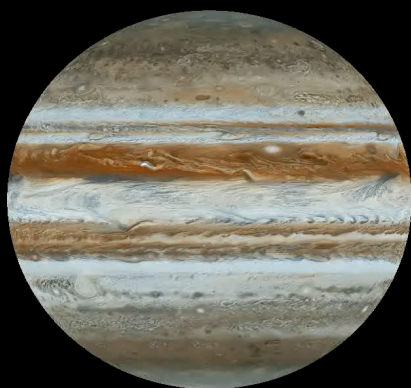
# Global magnetic field net



- For 180509 reference trajectory

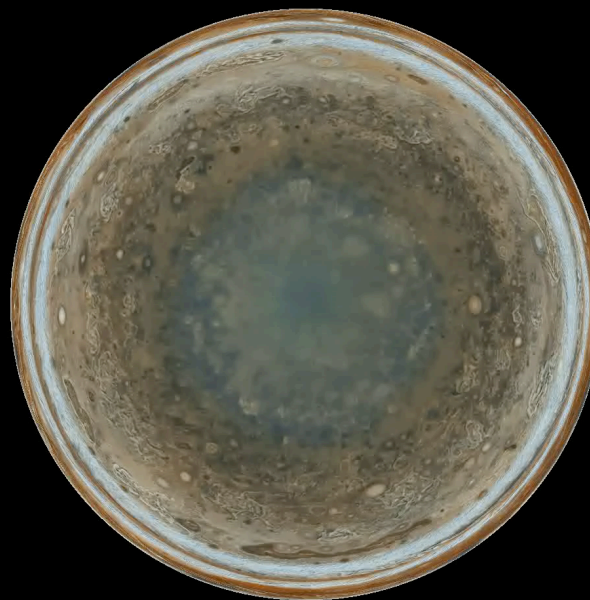
# Global magnetic field net animation through PJ15

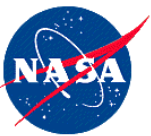
Juno Magnetic Field Net – Equatorial View – Perijoves 1 and 3-15



Equator Crossing Longitude – Perijoves 1 and 3-15  
2016/08/25 00:00:00.0000 UTC

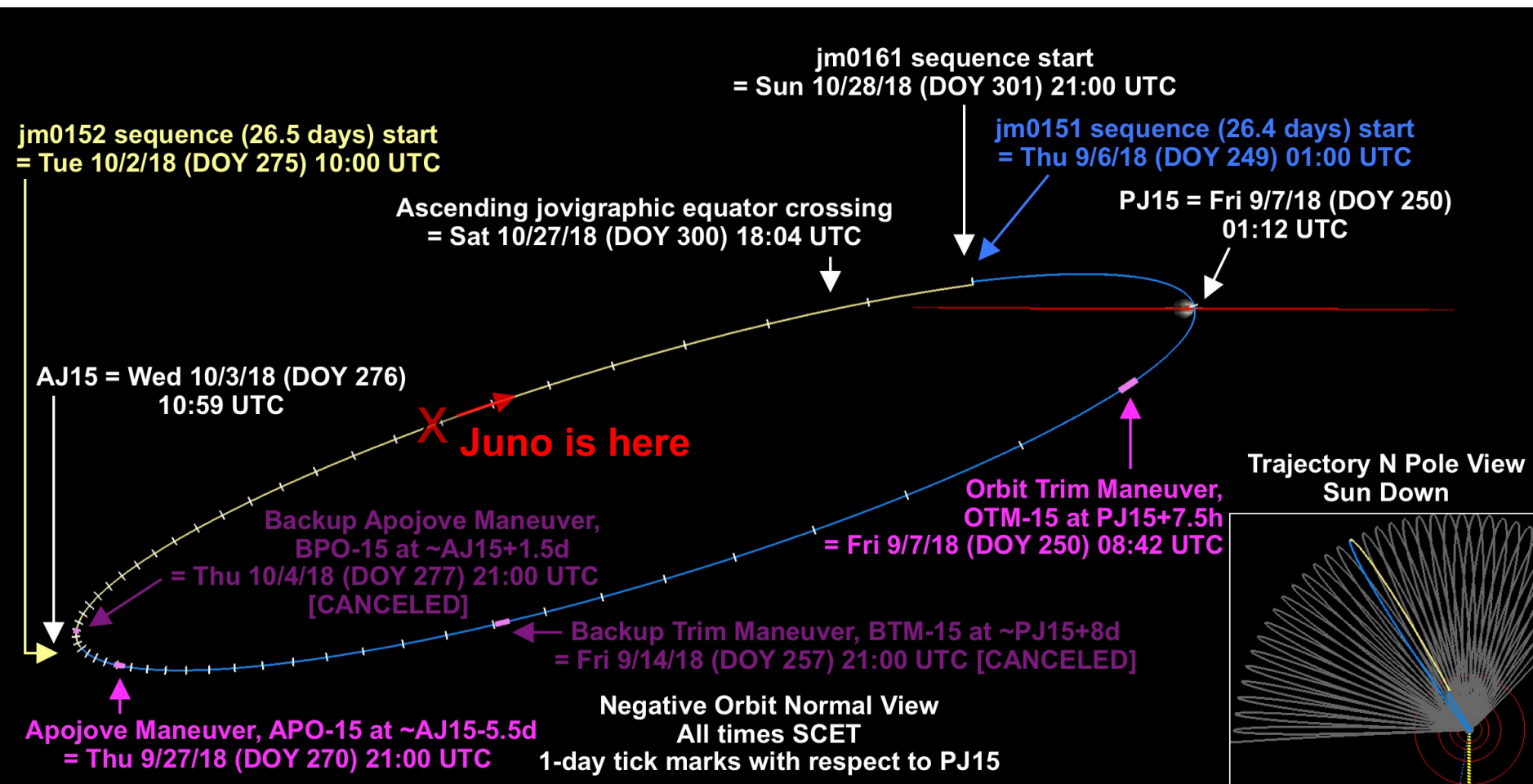
Juno Magnetic Field Net – N Pole View – Perijoves 1 and 3-15





# Orbit 15 = jm0151 + jm0152 sequences (PJ15-1d on 9/6/18 until PJ16-1d on 10/28/18)

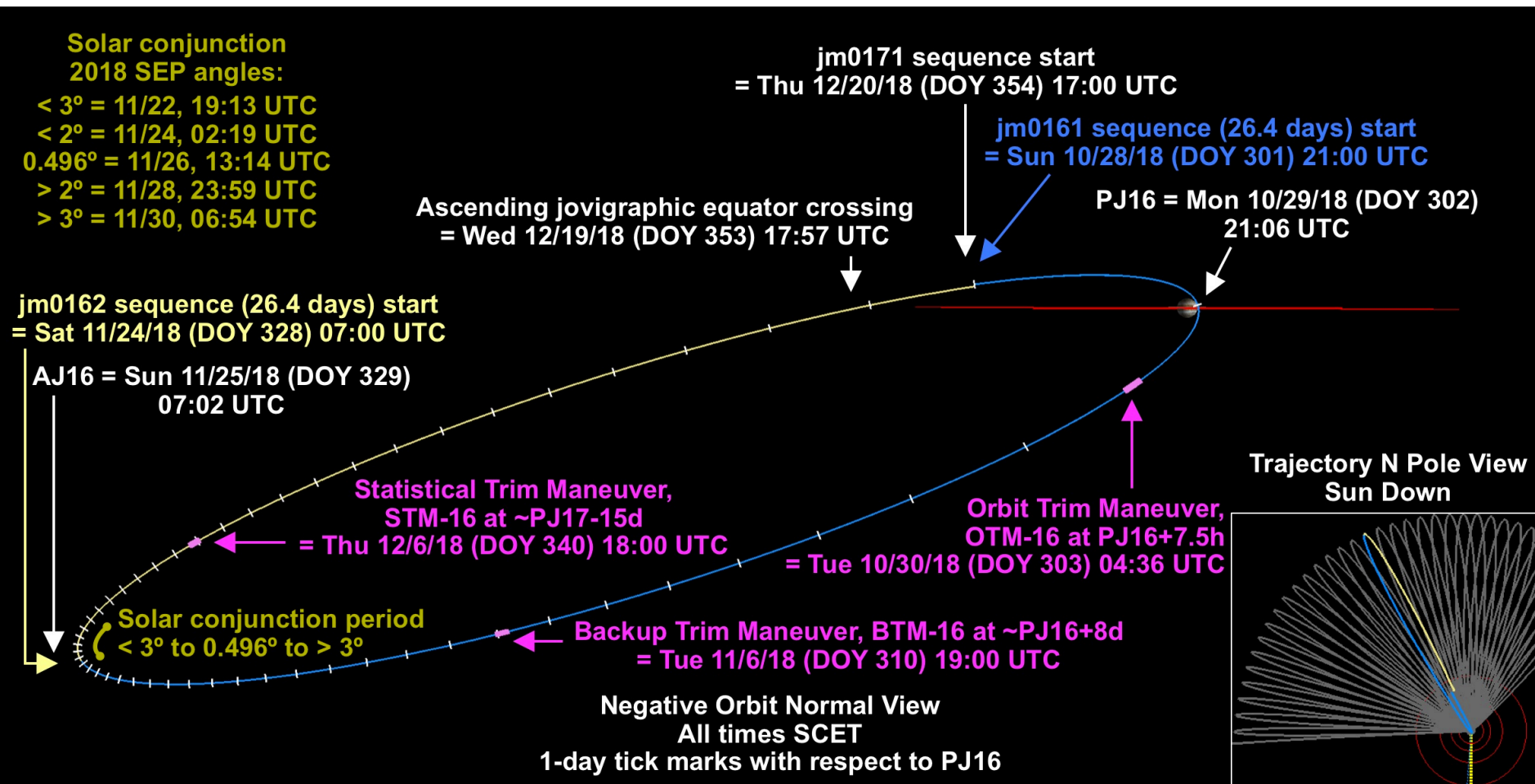
- This orbit started ~1 day before PJ15 and is divided into 2 sequences and activity periods:

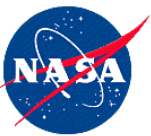




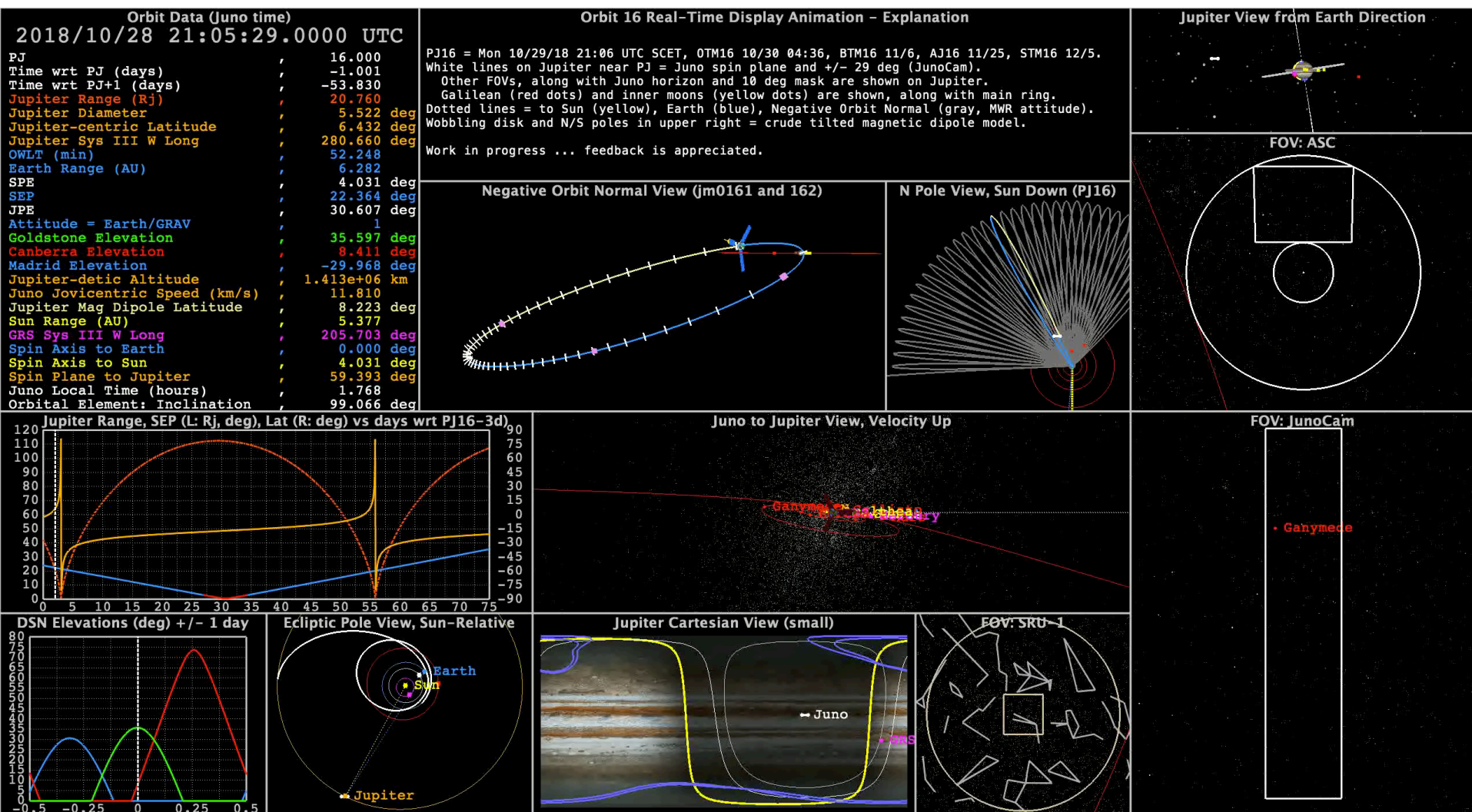
# Orbit 16 = jm0161 + jm0162 sequences (PJ16-1d on 10/28/18 until PJ17-1d on 12/20/18)

- This orbit starts ~1 day before PJ16 and is divided into 2 sequences and activity periods:





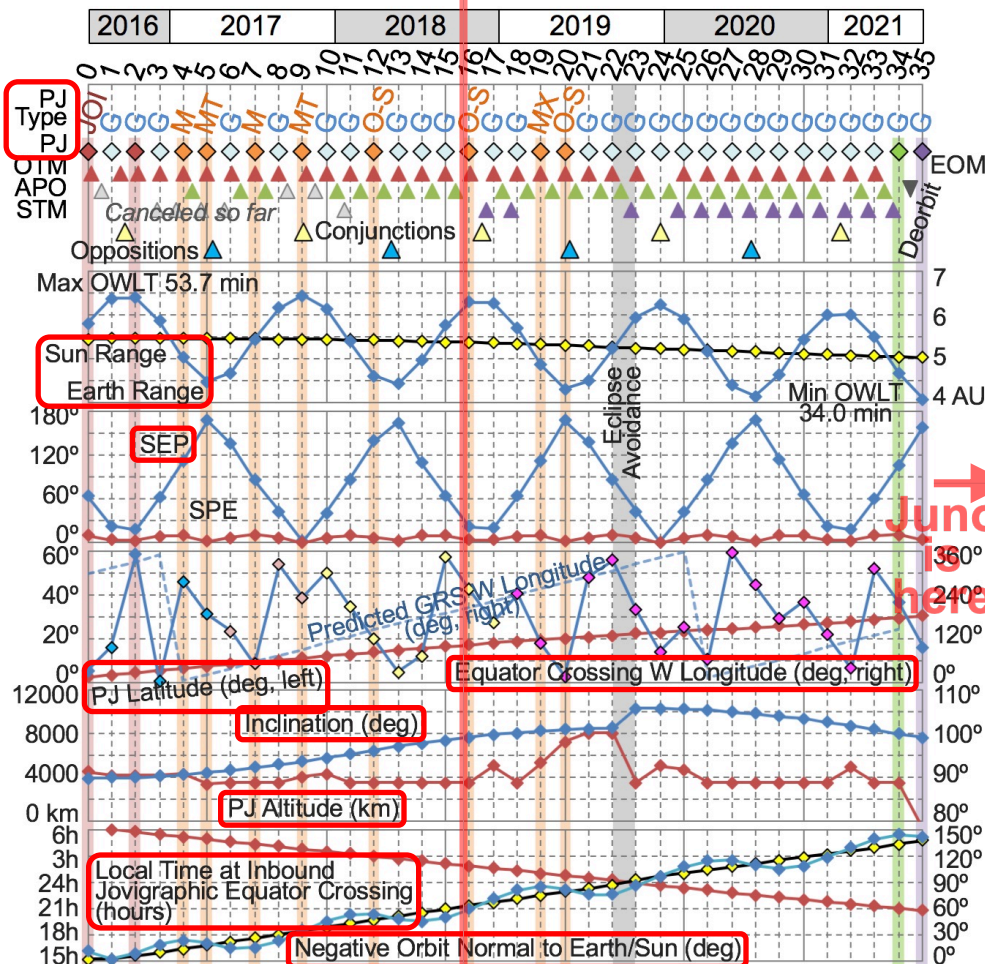
# PJ16 flyby animation: PJ16-1d to +1d (time step 30 min + 1 sec, to show S/C rotation)





# Plots of geometry vs. perijove

- Baseline PJ attitudes, maneuvers, ranges, angles, local times, etc., for 180509 trajectory (best viewed in PowerPoint slide show mode – click on animation right-arrow buttons):

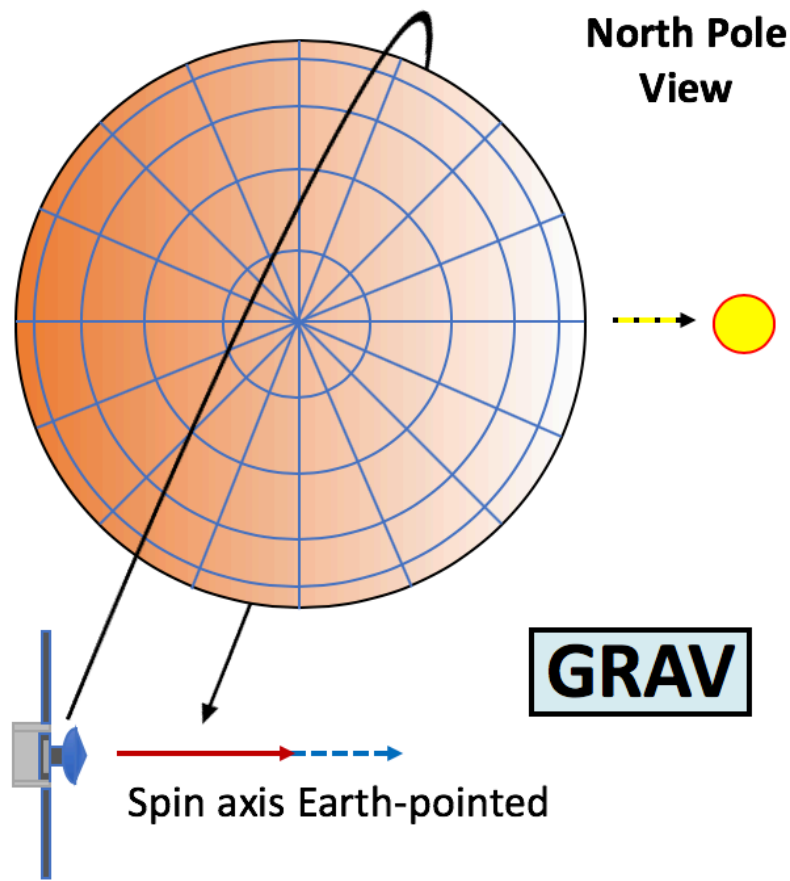


Perijove data to right are specified at perijove, except last 2 columns)			Ranges		Inc (°)	Oblate Altitude (km)	Lat (°)	Off-Sun Angle (°)	SEP (°)	Sys III W Long at EqX (°)	Local Time at AJ (hrs)
#	Type	Date (UTC)	Sun (AU)	Earth (AU)							
0	JOI	Jul 5, 2016	5.44	5.81	89.8	4494	2.7	91.8	64.1	33.3	6.0
1	PJ1	Aug 27, 2016	5.45	6.37	89.9	4163	3.8	4.1	22.6	96.6	5.7
2	Post-SM	Oct 19, 2016	5.45	6.39	90.0	4179	4.7	3.3	18.2	348.8	5.5
3	GRAV	Dec 11, 2016	5.46	5.85	90.2	4153	5.6	9.1	61.6	6.8	5.2
4	MWR	Feb 2, 2017	5.46	5.03	90.6	4304	6.6	14.2	110.8	276.5	4.9
5	MWR Tilt	Mar 27, 2017	5.46	4.48	91.0	3404	7.5	25.0	167.1	186.8	4.7
6	GRAV	May 19, 2017	5.45	4.69	91.6	3496	8.5	7.5	135.4	142.0	4.4
7	MWR	Jul 11, 2017	5.45	5.43	92.2	3500	9.5	26.4	85.7	51.9	4.2
8	GRAV	Sep 1, 2017	5.45	6.15	92.9	3501	10.4	7.2	42.5	321.9	3.9
9	MWR Tilt	Oct 24, 2017	5.44	6.44	93.6	4037	11.3	35.0	1.9	231.7	3.6
10	GRAV	Dec 16, 2017	5.43	6.14	94.4	4318	12.2	6.8	40.8	299.1	3.4
11	GRAV	Feb 7, 2018	5.43	5.39	95.3	3496	13.1	10.5	86.9	209.3	3.1
12	-30/+20	Apr 1, 2018	5.42	4.62	96.1	3497	13.9	35.0	139.2	119.3	2.9
13	GRAV	May 24, 2018	5.41	4.43	97.0	3499	14.8	3.1	163.4	29.3	2.6
14	GRAV	Jul 16, 2018	5.39	4.97	97.7	3501	15.7	10.2	109.7	74.3	2.4
15	GRAV	Sep 7, 2018	5.38	5.75	98.4	3500	16.6	9.7	63.6	344.3	2.1
16	-30/+20	Oct 29, 2018	5.37	6.28	99.0	3500	17.4	35.0	21.5	254.5	1.9
17	GRAV	Dec 21, 2018	5.35	6.26	99.6	5051	18.1	3.6	20.2	164.5	1.7
18	GRAV	Feb 12, 2019	5.34	5.69	100.1	3499	18.9	9.6	64.0	243.3	1.4
19	MWR XTK	Apr 6, 2019	5.32	4.86	100.5	5296	19.7	78.0	112.1	108.3	1.2
20	-30/+5	May 29, 2019	5.30	4.31	100.8	7240	20.3	30.7	166.7	18.2	0.9
21	GRAV	Jul 21, 2019	5.29	4.50	101.0	7976	21.0	7.5	137.1	288.3	0.7
22	GRAV	Sep 12, 2019	5.27	5.22	101.1	7974	21.7	11.0	86.9	333.2	0.4
23	GRAV	Nov 3, 2019	5.25	5.93	105.7	3500	22.5	7.4	42.7	198.2	0.2
24	GRAV	Dec 26, 2019	5.23	6.21	105.6	5035	22.9	0.2	0.8	85.8	23.9
25	GRAV	Feb 17, 2020	5.21	5.91	105.5	4701	23.5	7.2	41.3	153.3	23.7
26	GRAV	Apr 10, 2020	5.19	5.17	105.3	3501	24.1	11.1	85.7	63.2	23.4
27	GRAV	Jun 2, 2020	5.17	4.40	104.9	3499	24.7	7.9	135.7	355.8	23.2
28	GRAV	Jul 25, 2020	5.15	4.15	104.4	3500	25.3	2.3	168.2	265.7	22.9
29	GRAV	Sep 16, 2020	5.13	4.64	103.9	3500	25.9	10.3	113.7	175.8	22.6
30	GRAV	Nov 8, 2020	5.11	5.44	103.2	3499	26.6	10.2	66.0	220.8	22.4
31	GRAV	Dec 30, 2020	5.10	5.99	102.5	3499	27.3	4.3	22.9	130.7	22.1
32	GRAV	Feb 21, 2021	5.08	6.01	101.6	4883	28.0	3.5	18.4	40.8	21.8
33	GRAV	Apr 15, 2021	5.06	5.49	100.8	3499	28.8	9.9	59.9	310.7	21.6
34	Extra	Jun 7, 2021	5.05	4.69	99.9	3501	29.5	11.2	105.0	220.8	21.3
35	Deorbit	Jul 30, 2021	5.03	4.08	98.9	-698	30.5	4.4	157.4		

SEP = Sun-Earth-Probe angle, SPE = Sun-Probe-Earth angle, EOM = end of mission, OWLT = one-way light time

# Perijove attitudes – GRAV, MWR, MWR tilt, (proposed) MWR cross-track, and off-Sun

- PJ attitudes – **GRAV**, **MWR**, **MWR tilt**, (proposed) **MWR cross-track**, and **off-Sun** – visualized by Marty Brennan (see his individual explanations in backup slides):



- To see all 5 views, use PowerPoint slide show mode, and click through
- Note this is for only one orientation of the orbit with respect to the Sun (one Neg Orbit Normal to Sun angle)
- For some mid-mission orbits, to get better viewing geometries for JADE, JEDI, UVS, and other remote sensing instruments, we use **off-Sun** attitudes such as -30/+20 – which means spin axis turned -30 deg in azimuth (in the dawn direction wrt the Sun), and +20 deg in elevation (out of Jupiter's equator plane). The geometry in these off-Sun attitudes has some similarities to that for MWR tilt attitudes.



## Baseline reference trajectory (SPICE kernel or SPK file)

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- Latest 180509 **reference trajectory** (spk\_ref\_180429\_210731\_180509.bsp) is available at:
  - NAIF public server: <https://naif.jpl.nasa.gov/pub/naif/JUNO/kernels/spk/>
  - This is the SPICE kernel (SPK file) for the current baseline reference trajectory
  - It starts > PJ12, so use reconstructed SPK files for earlier parts of the trajectory



Latest file  
(9/23/2018),  
**8 total pages**

**<--- Latest reference trajectory**

From Nav
From SOAP
Formula/Other



# Orbital data useful for science planning [2/8]

Juno Orbital Data (180509 Reference Trajectory)			Alt wrt Oblate Jupiter (km)	Jupiter Range (Rj)	Min Alt Post-PJ (km)	Min Alt Time wrt PJ (mm:ss)	Lat (°)	Approx Magnetic Latitude (°)	Sys III W Long (°)	Approx Magnetic Field (Gauss)	Local Time (hrs)	NON to Sun (°)	NON to Earth (°)	NTON to Sun (°)	NTON to Earth (°)	Sun Speed on Sky (°/day)	Earth Speed on Sky (°/day)	Dec at DSN (°)
#	Type	Time (UTC/SCET)																
0	JOI	07/05/2016 02:47:32	4494	1.063	4491	+ 00:13	2.7	-6.7	32.7	4.1	18.1	2.9	12.0	16.0	19.4	0.4	0.4	6.0
1	PJ1	08/27/2016 12:50:44	4163	1.058	4158	+ 00:19	3.8	1.1	95.8	4.8	17.9	2.7	2.8	16.1	15.9	0.4	0.3	2.1
2	Post-SM	10/19/2016 18:10:54	4179	1.058	4172	+ 00:23	4.7	-3.3	347.7	3.6	17.6	6.3	9.4	17.3	18.6	0.3	0.3	-2.4
3	GRAV	12/11/2016 17:03:41	4153	1.057	4143	+ 00:27	5.6	-3.6	5.5	3.7	17.3	10.2	19.2	19.3	25.3	0.3	0.3	-6.1
4	MWR	02/02/2017 12:57:09	4304	1.059	4290	+ 00:32	6.6	9.3	274.9	3.7	17.1	14.2	23.9	22.0	29.2	0.3	0.4	-7.7
5	MWR Tilt	03/27/2017 08:51:52	3404	1.046	3386	+ 00:36	7.5	16.7	184.9	8.5	16.8	18.3	20.6	25.0	27.0	0.3	0.5	-6.2
6	GRAV	05/19/2017 06:00:47	3496	1.047	3473	+ 00:41	8.5	12.9	139.8	8.2	16.6	22.3	15.1	28.4	23.3	0.3	0.4	-4.1
7	MWR	07/11/2017 01:54:42	3500	1.047	3470	+ 00:46	9.5	0.9	49.4	3.9	16.3	26.4	16.0	32.0	24.1	0.3	0.4	-4.6
8	GRAV	09/01/2017 21:48:50	3501	1.047	3465	+ 00:51	10.4	5.9	319.0	4.2	16.0	30.5	23.4	35.6	29.8	0.3	0.3	-7.6
9	MWR Tilt	10/24/2017 17:42:31	4037	1.054	3995	+ 00:55	11.3	19.9	228.4	4.7	15.8	34.6	34.3	39.4	39.0	0.3	0.3	-11.6
10	GRAV	12/16/2017 17:56:59	4318	1.057	4271	+ 00:59	12.2	11.5	295.3	4.3	15.5	38.8	45.5	43.2	49.1	0.3	0.3	-15.1
11	GRAV	02/07/2018 13:51:30	3496	1.045	3443	+ 01:02	13.1	22.7	205.1	7.0	15.3	42.9	53.2	47.1	56.4	0.3	0.3	-17.1
12	-30/+20	04/01/2018 09:45:43	3497	1.045	3437	+ 01:06	13.9	14.2	114.6	6.4	15.0	47.0	53.9	50.9	57.2	0.3	0.4	-17.2
13	GRAV	05/24/2018 05:39:50	3499	1.044	3430	+ 01:11	14.8	5.3	24.0	3.2	14.8	51.2	48.2	54.8	52.2	0.3	0.4	-15.6
14	GRAV	07/16/2018 05:17:39	3501	1.044	3425	+ 01:14	15.7	9.0	68.7	6.7	14.5	55.2	45.3	58.6	49.7	0.3	0.4	-14.9
15	GRAV	09/07/2018 01:11:57	3500	1.043	3418	+ 01:17	16.6	9.5	338.2	5.4	14.3	59.3	49.8	62.3	53.8	0.3	0.3	-16.4
16	-30/+20	10/29/2018 21:06:17	3500	1.043	3411	+ 01:21	17.4	24.0	247.6	5.8	14.0	63.3	59.5	66.0	62.5	0.3	0.3	-19.0
17	GRAV	12/21/2018 17:00:27	5051	1.064	4958	+ 01:25	18.1	24.8	157.0	11.3	13.8	67.3	70.8	69.8	73.0	0.3	0.4	-21.3
18	GRAV	02/12/2019 17:34:16	3499	1.042	3397	+ 01:27	18.9	26.9	235.3	6.7	13.5	71.3	80.6	73.4	82.0	0.3	0.4	-22.4
19	MWR Xtk	04/06/2019 12:14:00	5296	1.066	5190	+ 01:31	19.7	17.3	99.7	6.3	13.3	75.2	85.1	77.1	86.1	0.3	0.4	-22.7
20	-30/+5	05/29/2019 08:08:14	7240	1.093	7131	+ 01:35	20.3	11.0	9.1	3.5	13.0	79.2	81.7	80.7	83.0	0.3	0.4	-22.5
21	GRAV	07/21/2019 04:02:44	7976	1.103	7860	+ 01:39	21.0	22.9	278.6	4.1	12.8	83.1	75.7	84.2	77.5	0.3	0.4	-22.1
22	GRAV	09/12/2019 03:40:47	7974	1.102	7855	+ 01:41	21.7	16.5	323.3	4.6	12.5	86.9	76.2	87.8	77.9	0.3	0.3	-22.4
23	GRAV	11/03/2019 22:18:14	3500	1.039	3369	+ 01:39	22.5	31.7	186.2	11.9	12.3	93.0	85.9	93.2	86.9	0.4	0.4	-23.1
24	GRAV	12/26/2019 17:35:57	5035	1.060	4904	+ 01:42	22.9	16.7	73.3	6.5	12.0	96.5	96.4	96.4	96.3	0.4	0.4	-23.2
25	GRAV	02/17/2020 17:51:42	4701	1.055	4562	+ 01:44	23.5	27.8	140.6	11.4	11.8	100.2	107.1	99.7	105.8	0.4	0.4	-22.3
26	GRAV	04/10/2020 13:47:11	3501	1.037	3354	+ 01:46	24.1	15.6	50.5	4.8	11.5	103.8	114.4	102.9	112.3	0.4	0.4	-21.1
27	GRAV	06/02/2020 10:19:47	3499	1.037	3348	+ 01:47	24.7	17.1	342.9	6.1	11.3	107.4	114.9	106.1	112.8	0.4	0.4	-21.0
28	GRAV	07/25/2020 06:15:14	3500	1.036	3342	+ 01:50	25.3	31.1	252.8	6.7	11.0	111.0	108.8	109.3	107.3	0.4	0.4	-22.2
29	GRAV	09/16/2020 02:10:43	3500	1.036	3335	+ 01:52	25.9	33.2	162.7	13.9	10.8	114.6	104.7	112.6	103.7	0.4	0.4	-22.7
30	GRAV	11/08/2020 01:49:34	3499	1.035	3328	+ 01:54	26.6	36.1	207.7	10.2	10.5	118.3	108.5	115.8	107.1	0.4	0.4	-22.1
31	GRAV	12/30/2020 21:45:08	3499	1.034	3321	+ 01:57	27.3	27.8	117.7	9.4	10.3	121.9	117.8	119.1	115.5	0.4	0.5	-20.1
32	GRAV	02/21/2021 17:40:27	4883	1.053	4701	+ 02:00	28.0	18.4	27.7	3.6	10.0	125.6	129.0	122.5	125.5	0.4	0.5	-16.9
33	GRAV	04/15/2021 13:36:23	3499	1.033	3305	+ 02:02	28.8	27.3	298.0	5.6	9.7	129.3	138.8	125.9	134.0	0.4	0.5	-13.5
34	Extra	06/07/2021 09:32:00	3501	1.032	3297	+ 02:05	29.5	39.1	208.1	10.5	9.4	133.1	143.8	129.3	138.2	0.4	0.4	-11.6
35	Deorbit	07/30/2021 04:32:45	-698	0.972	-925	+ 02:04	30.5	25.8	85.1	9.3	9.2	136.9	141.1	132.8	136.2	0.4	0.4	-12.6

← Latest reference trajectory

Using [spk\\_ref\\_180429\\_210731\\_180509.bsp](#) (latest reference trajectory) after AJ12. The latest reconstructed trajectories are used for AJ12 and earlier. Data are for PJ (perijove) unless stated otherwise. P19 attitude is in the MWR Tilt direction, but truncated at 35 deg off-Sun (vs. 39.4 deg for MWR Tilt). P12 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). P16 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). P20 attitude is in the MWG-desired -30/+5 (az/el) direction (30.4 deg off-Sun, so no need for truncation). Future PJ attitudes are preliminary. Cells are highlighted (shaded gray) to point out: before/after ~7 longitude shifts, non-prime shift, weekends, minima/maxima, >4.5 G mag field, opposition/conjunction, SPE ≤ 3.05°, Far EqX distance wrt Galilean satellite orbital ansae, 70-m down times. **MT** = Mountain Time. **PT** = Pacific Time. **DOY** = day of year. **DOW** = day of week. **OWLT** = one-way light time. **NON** = negative orbit normal. **NTON** = negative tilted orbit normal. **S** = Sun, **P** = Probe, **E** = Earth, **J** = Jupiter in **SPE**, **SEP**, **JPE**, **SJP**. **Xtk** = crosstrack (Juno +Z aligned with Jupiter S pole then tilted 1.5 deg E and 10 deg N for MWR). **EqX** = (outbound) equator crossing. **Far EqX** = inbound equator crossing. Altitudes are Jupiter-detic, and latitudes are Jupiter-centric. Rj = 71,492 km.

From Nav
From SOAP
Formula/Other



# Orbital data useful for science planning [3/8]

Juno Orbital Data (180509 Reference Trajectory)			Off-Sun Angle (°)					Off-Earth Angle (°)					+/- SPE (°)	SEP (°)	ESP (°)	JPE (°)	J-P- NTON (°)	EJP (°)	SPJ (°)	SJP (°)	SEJ (°)	SJE (°)	ESJ (°)
Perijove			Base- line	MWR	Tilt	Other	GRAV	Base- line	MWR	Tilt	Other	GRAV											
#	Type	Time (UTC/SCET)																					
0	JOI	07/05/2016 02:47:32	91.8	2.9	16.0		9.7	91.0	12.0	19.4		0.0	9.7	64.1	106.2	78.0	90.7	101.9	87.7	92.3	64.1	9.7	106.2
1	PJ1	08/27/2016 12:50:44	4.1	2.7	16.1		4.1	0.0	2.8	15.9		0.0	4.1	22.6	153.3	87.6	90.9	92.4	91.7	88.3	22.6	4.1	153.3
2	Post-SM	10/19/2016 18:10:54	3.3	6.3	17.3		3.3	0.0	9.4	18.6		0.0	-3.3	18.2	158.6	98.9	91.1	81.1	95.6	84.3	18.2	3.3	158.6
3	GRAV	12/11/2016 17:03:41	9.1	10.2	19.3		9.1	0.0	19.2	25.3		0.0	-9.1	61.6	109.3	108.6	91.4	71.4	99.6	80.4	61.6	9.1	109.3
4	MWR	02/02/2017 12:57:09	14.2	14.2	22.0		9.7	23.9	23.9	29.2		0.0	-9.7	110.8	59.5	113.0	91.6	67.0	103.4	76.6	110.8	9.7	59.5
5	MWR Tilt	03/27/2017 08:51:52	25.0	18.3	25.0		2.3	27.0	20.6	27.0		0.0	-2.3	167.1	10.6	109.4	91.8	70.6	107.2	72.8	167.1	2.3	10.6
6	GRAV	05/19/2017 06:00:47	7.5	22.3	28.4		7.5	0.0	15.1	23.3		0.0	7.5	135.4	37.1	103.6	92.0	76.4	111.0	69.0	135.4	7.5	37.1
7	MWR	07/11/2017 01:54:42	26.4	26.4	32.0		10.7	16.0	16.0	24.1		0.0	10.7	85.7	83.6	104.2	92.3	75.8	114.6	65.4	85.7	10.7	83.6
8	GRAV	09/01/2017 21:48:50	7.2	30.5	35.6		7.2	0.0	23.4	29.8		0.0	7.2	42.5	130.3	111.3	92.5	68.7	118.3	61.7	42.5	7.2	130.3
9	MWR Tilt	10/24/2017 17:42:31	35.0	34.6	39.4	35.0	0.3	34.7	34.3	39.0	34.7	0.0	0.3	1.9	177.8	121.6	92.7	58.4	121.8	58.2	1.9	0.3	177.8
10	GRAV	12/16/2017 17:56:59	6.8	38.8	43.2		6.8	0.0	45.5	49.1		0.0	-6.8	40.8	132.4	131.8	92.9	48.2	125.3	54.7	40.8	6.8	132.4
11	GRAV	02/07/2018 13:51:30	10.5	42.9	47.1		10.5	0.0	53.2	56.4		0.0	-10.5	86.9	82.7	138.3	93.1	41.7	128.7	51.3	86.8	10.5	82.7
12	-30/+20	04/01/2018 09:45:43	35.0	47.0	50.9	35.0	6.9	40.9	53.9	57.2	40.9	0.0	-6.9	139.2	33.9	138.2	93.4	41.8	131.9	48.1	139.2	6.9	33.9
13	GRAV	05/24/2018 05:39:50	3.1	51.2	54.8		3.1	0.0	48.2	52.2		0.0	3.1	163.4	13.5	132.2	93.6	47.8	135.0	45.0	163.4	3.1	13.5
14	GRAV	07/16/2018 05:17:39	10.2	55.2	58.6		10.2	0.0	45.3	49.7		0.0	10.2	109.7	60.1	128.9	93.8	51.1	138.1	41.9	109.7	10.2	60.1
15	GRAV	09/07/2018 01:11:57	9.7	59.3	62.3		9.7	0.0	49.8	53.8		0.0	9.7	63.6	106.7	132.5	94.0	47.5	141.0	39.0	63.7	9.7	106.7
16	-30/+20	10/29/2018 21:06:17	35.0	63.3	66.0	35.0	3.9	31.8	59.5	62.5	31.8	0.0	3.9	21.5	154.6	140.5	94.2	39.5	143.6	36.4	21.5	3.9	154.6
17	GRAV	12/21/2018 17:00:27	3.6	67.3	69.8		3.6	0.0	70.8	73.0		0.0	-3.6	20.2	156.1	149.0	94.4	31.0	146.2	33.8	20.2	3.6	156.2
18	GRAV	02/12/2019 17:34:16	9.6	71.3	73.4		9.6	0.0	80.6	82.0		0.0	-9.6	64.0	106.4	154.5	94.6	25.5	148.5	31.5	64.0	9.6	106.4
19	MWR Xtk	04/06/2019 12:14:00	78.0	75.2	77.1	78.0	10.0	77.4	85.1	86.1	77.4	0.0	-10.0	112.1	57.9	155.8	94.7	24.2	150.6	29.4	112.1	10.0	57.9
20	-30/+5	05/29/2019 08:08:14	30.4	79.2	80.7	30.4	2.5	32.9	81.7	83.0	32.9	0.0	-2.5	166.7	10.8	153.6	94.9	26.4	152.3	27.6	166.7	2.5	10.8
21	GRAV	07/21/2019 04:02:44	7.5	83.1	84.2		7.5	0.0	75.7	77.5		0.0	7.5	137.1	35.4	149.6	95.1	30.4	153.7	26.3	137.1	7.5	35.4
22	GRAV	09/12/2019 03:40:47	11.0	86.9	87.8		11.0	0.0	76.2	77.9		0.0	11.0	86.9	82.1	149.5	95.2	30.5	154.7	25.3	86.9	11.0	82.1
23	GRAV	11/03/2019 22:18:14	7.4	93.0	93.2		7.4	0.0	85.9	86.9		0.0	7.4	42.7	129.9	152.7	95.5	27.3	154.9	25.1	42.7	7.4	129.9
24	GRAV	12/26/2019 17:35:57	0.2	96.5	96.4		0.2	0.0	96.4	96.3		0.0	0.2	0.8	179.0	155.0	95.6	25.0	155.0	25.0	0.8	0.2	179.0
25	GRAV	02/17/2020 17:51:42	7.2	100.2	99.7		7.2	0.0	107.1	105.8		0.0	-7.2	41.3	131.5	152.8	95.7	27.2	154.4	25.6	41.3	7.2	131.5
26	GRAV	04/10/2020 13:47:11	11.1	103.8	102.9		11.1	0.0	114.4	112.3		0.0	-11.1	85.7	83.2	149.1	95.9	30.9	153.4	26.6	85.7	11.1	83.2
27	GRAV	06/02/2020 10:19:47	7.9	107.4	106.1		7.9	0.0	114.9	112.8		0.0	-7.9	135.7	36.5	148.5	96.0	31.5	151.9	28.1	135.7	7.9	36.5
28	GRAV	07/25/2020 06:15:14	2.3	111.0	109.3		2.3	0.0	108.8	107.3		0.0	2.3	168.2	9.5	151.0	96.1	29.0	150.0	30.0	168.2	2.3	9.5
29	GRAV	09/16/2020 02:10:43	10.3	114.6	112.6		10.3	0.0	104.7	103.7		0.0	10.3	113.7	55.9	151.7	96.3	28.3	147.8	32.2	113.7	10.3	55.9
30	GRAV	11/08/2020 01:49:34	10.2	118.3	115.8		10.2	0.0	108.5	107.1		0.0	10.2	66.0	103.8	150.0	96.4	30.0	145.3	34.7	66.0	10.2	103.8
31	GRAV	12/30/2020 21:45:08	4.3	121.9	119.1		4.3	0.0	117.8	115.5		0.0	4.3	22.9	152.8	145.0	96.5	35.0	142.5	37.5	22.9	4.3	152.8
32	GRAV	02/21/2021 17:40:27	3.5	125.6	122.5		3.5	0.0	129.0	125.5		0.0	-3.5	18.4	158.1	137.1	96.7	42.9	139.6	40.4	18.4	3.5	158.1
33	GRAV	04/15/2021 13:36:23	9.9	129.3	125.9		9.9	0.0	138.8	134.0		0.0	-9.9	59.9	110.2	129.2	96.8	50.8	136.4	43.6	59.9	9.9	110.2
34	Extra	06/07/2021 09:32:00	11.2	133.1	129.3		11.2	0.0	143.8	138.2		0.0	-11.2	105.0	63.8	124.8	97.0	55.2	133.2	46.8	105.0	11.2	63.8
35	Deorbit	07/30/2021 04:32:45	4.4	136.9	132.8		4.4	0.0	141.1	136.2		0.0	-4.4	157.4	18.1	126.6	97.1	53.4	129.8	50.2	157.4	4.4	18.1

← Latest reference trajectory

Using [spk\\_ref\\_180429\\_210731\\_180509.bsp](#) (latest reference trajectory) after AJ12. The latest reconstructed trajectories are used for AJ12 and earlier. Data are for PJ (perijove) unless stated otherwise. P19 attitude is in the MWR Tilt direction, but truncated at 35 deg off-Sun (vs. 39.4 deg for MWR Tilt). P12 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). P16 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). P20 attitude is in the MWG-desired -30/+5 (az/el) direction (30.4 deg off-Sun, so no need for truncation). Future PJ attitudes are preliminary. Cells are highlighted (shaded gray) to point out: before/after ~7 longitude shifts, non-prime shift, weekends, minima/maxima, >4.5 G mag field, opposition/conjunction, SPE ≤ 3.05°, Far EqX distance wrt Galilean satellite orbital ansae, 70-m down times. **MT** = Mountain Time. **PT** = Pacific Time. **DOY** = day of year. **DOW** = day of week. **OWLT** = one-way light time. **NON** = negative orbit normal. **NTON** = negative tilted orbit normal. **S** = Sun, **P** = Probe, **E** = Earth, **J** = Jupiter in **SPE**, **SEP**, **JPE**, **SJP**. **Xtk** = crosstrack (Juno +Z aligned with Jupiter S pole then tilted 1.5 deg E and 10 deg N for MWR). **EqX** = (outbound) equator crossing. **Far EqX** = inbound equator crossing. Altitudes are Jupiter-detic, and latitudes are Jupiter-centric. Rj = 71,492 km.

From Nav
From SOAP
Formula/Other



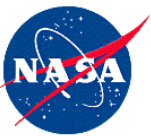
# Orbital data useful for science planning [4/8]

## Great Red Spot predicts

Juno Orbital Data (180509 Reference Trajectory)					Time wrt PJ at EqX (mm:ss)	Jupiter Range at EqX (Rj)	Alt wrt Jupiter at EqX (km)	JPE at EqX (°)	Local Time at EqX (hrs)	Sys III W Long at EqX (°)	Alt wrt Jupiter at -20°S (km)	Sys III W Long at -20°S (°)	GRS Sys III W Long (°)	GRS Sys III σ (°)	Juno wrt GRS W Long (°)	+Z to S/C Dust Ram Angle at EqX (°)			S/C Dust Ram Speed (km/s)	
Perijove			Equator Crossing														Base- line	Other	GRAV	
#	Type	Time (UTC/SCET)	#	Time (UTC/SCET)																
0	JOI	07/05/2016 02:47:32	0	07/05/2016 02:48:35	+ 01:03	1.063	4526	78.1	18.1	33.3	8093	38	295	± 0.3	103	144.8	144.8	54.5	70.8	
1	PJ1	08/27/2016 12:50:44	1	08/27/2016 12:52:10	+ 01:26	1.059	4220	87.7	17.9	96.6	8002	101	313	± 0.9	149	53.1		53.1	70.7	
2	Post-SM	10/19/2016 18:10:54	2	10/19/2016 18:12:41	+ 01:47	1.060	4269	99.1	17.6	348.8	8273	354	330	± 1.6	23	52.6		52.6	70.8	
3	GRAV	12/11/2016 17:03:41	3	12/11/2016 17:05:50	+ 02:09	1.060	4284	109.0	17.3	6.8	8517	12	348	± 2.3	24	53.3		53.3	70.9	
4	MWR	02/02/2017 12:57:09	4	02/02/2017 12:59:40	+ 02:31	1.063	4482	113.6	17.1	276.5	8952	282	5	± 3.0	276	54.9	54.9	53.6	71.0	
5	MWR Tilt	03/27/2017 08:51:52	5	03/27/2017 08:54:42	+ 02:50	1.051	3636	110.2	16.8	186.8	8294	192	23	± 3.7	169	69.0	69.0	52.3	71.7	
6	GRAV	05/19/2017 06:00:47	6	05/19/2017 06:03:59	+ 03:12	1.053	3790	104.4	16.5	142.0	8688	147	40	± 0.3	107	51.2		51.2	71.9	
7	MWR	07/11/2017 01:54:42	7	07/11/2017 01:58:16	+ 03:34	1.054	3863	105.2	16.3	51.9	9002	58	58	± 1.0	360	55.4	55.4	50.9	72.3	
8	GRAV	09/01/2017 21:48:50	8	09/01/2017 21:52:45	+ 03:55	1.055	3938	112.8	16.0	321.9	9319	328	75	± 1.7	253	51.6		51.6	72.6	
9	MWR Tilt	10/24/2017 17:42:31	9	10/24/2017 17:46:50	+ 04:19	1.064	4564	123.7	15.7	231.7	10220	238	92	± 2.4	146	67.5	67.5	53.9	72.7	
10	GRAV	12/16/2017 17:56:59	10	12/16/2017 18:01:40	+ 04:41	1.069	4939	134.8	15.5	299.1	10860	306	110	± 3.1	196	57.5		57.5	72.9	
11	GRAV	02/07/2018 13:51:30	11	02/07/2018 13:56:27	+ 04:57	1.059	4206	142.5	15.2	209.3	10316	216	127	± 3.8	89	60.5		60.5	73.8	
12	-30/+20	04/01/2018 09:45:43	12	04/01/2018 09:51:00	+ 05:17	1.060	4308	143.0	14.9	119.3	10674	127	145	± 4.4	342	67.7	67.7	60.0	74.2	
13	GRAV	05/24/2018 05:39:50	13	05/24/2018 05:45:29	+ 05:39	1.062	4422	137.1	14.7	29.3	11042	37	162	± 5.1	235	56.6		56.6	74.6	
14	GRAV	07/16/2018 05:17:39	14	07/16/2018 05:23:39	+ 06:00	1.064	4546	134.0	14.4	74.5	11417	82	180	± 5.8	262	55.1		55.1	74.9	
15	GRAV	09/07/2018 01:11:57	15	09/07/2018 01:18:17	+ 06:20	1.065	4671	138.6	14.1	344.5	11808	353	189	± 0.3	163	56.6		56.6	75.2	
16	-30/+20	10/29/2018 21:06:17	16	10/29/2018 21:12:57	+ 06:40	1.067	4800	148.3	13.8	254.5	12199	263	206	± 0.9	57	68.5	68.5	61.4	75.5	
17	GRAV	12/21/2018 17:00:27	17	12/21/2018 17:07:38	+ 07:11	1.091	6514	159.8	13.6	164.5	14309	173	223	± 1.6	311	68.0		68.0	74.9	
18	GRAV	02/12/2019 17:34:16	18	02/12/2019 17:41:33	+ 07:17	1.071	5060	169.6	13.3	243.3	12963	252	240	± 2.3	13	74.1		74.1	75.9	
19	MWR XTK	04/06/2019 12:14:00	19	04/06/2019 12:21:52	+ 07:52	1.099	7052	173.8	13.0	108.3	15371	118	256	± 3.0	221	43.6	43.6	76.9	75.1	
20	-30/+5	05/29/2019 08:08:14	20	05/29/2019 08:16:42	+ 08:28	1.129	9193	170.6	12.8	18.2	17941	28	273	± 3.7	115	59.3	59.3	74.2	74.3	
21	GRAV	07/21/2019 04:02:44	21	07/21/2019 04:11:37	+ 08:53	1.141	10090	164.7	12.5	288.3	19146	298	290	± 4.4	8	70.1		70.1	74.0	
22	GRAV	09/12/2019 03:40:47	22	09/12/2019 03:49:57	+ 09:10	1.143	10236	165.2	12.2	333.2	19508	343	306	± 5.1	37	70.2		70.2	73.9	
23	GRAV	11/03/2019 22:18:14	23	11/03/2019 22:27:08	+ 08:54	1.082	5874	174.5	11.8	198.2	15294	210	323	± 5.8	246	76.5		76.5	78.3	
24	GRAV	12/26/2019 17:35:57	24	12/26/2019 17:45:19	+ 09:22	1.106	7584	173.6	11.6	85.8	17334	97	340	± 6.4	117	84.5		84.5	77.4	
25	GRAV	02/17/2020 17:51:42	25	02/17/2020 18:01:15	+ 09:33	1.103	7366	162.7	11.3	153.3	17244	165	357	± 7.1	168	92.6		92.6	77.4	
26	GRAV	04/10/2020 13:47:11	26	04/10/2020 13:56:44	+ 09:33	1.087	6239	155.0	11.1	63.2	16150	75	13	± 7.8	61	98.0		98.0	77.9	
27	GRAV	06/02/2020 10:19:47	27	06/02/2020 10:29:33	+ 09:46	1.089	6371	154.5	10.8	355.8	16441	7	30	± 8.5	337	98.3		98.3	77.6	
28	GRAV	07/25/2020 06:15:14	28	07/25/2020 06:25:14	+ 10:00	1.091	6504	160.9	10.6	265.7	16735	277	47	± 9.2	230	93.3		93.3	77.3	
29	GRAV	09/16/2020 02:10:43	29	09/16/2020 02:20:57	+ 10:14	1.093	6648	165.2	10.3	175.8	17044	187	64	± 9.9	123	90.0		90.0	76.9	
30	GRAV	11/08/2020 01:49:34	30	11/08/2020 02:00:02	+ 10:28	1.095	6795	161.3	10.1	220.8	17352	231	80	± 10.6	151	92.6		92.6	76.5	
31	GRAV	12/30/2020 21:45:08	31	12/30/2020 21:55:51	+ 10:43	1.097	6951	151.7	9.8	130.7	17691	141	97	± 11.3	44	99.2		99.2	76.1	
32	GRAV	02/21/2021 17:40:27	32	02/21/2021 17:51:44	+ 11:17	1.120	8592	140.1	9.6	40.8	19681	51	114	± 11.9	297	107.0		107.0	74.9	
33	GRAV	04/15/2021 13:36:23	33	04/15/2021 13:47:38	+ 11:15	1.102	7300	130.0	9.3	310.7	18389	321	131	± 12.6	190	113.3		113.3	75.0	
34	Extra	06/07/2021 09:32:00	34	06/07/2021 09:43:33	+ 11:33	1.105	7498	124.9	9.1	220.8	18787	230	147	± 13.3	83	116.3		116.3	74.5	
35	Deorbit	07/30/2021 04:32:45	35	07/30/2021 04:43:38	+ 10:53	1.045	3213	127.8	8.8	97.0						113.9		113.9	76.1	

Using [spk\\_ref\\_180429\\_210731\\_180509.bsp](#) (latest reference trajectory) after AJ12. The latest reconstructed trajectories are used for AJ12 and earlier. Data are for PJ (peri-jove) unless stated otherwise. P19 attitude is in the MWR Tilt direction, but truncated at 35 deg off-Sun (vs. 39.4 deg for MWR Tilt). P12 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). P16 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). P20 attitude is in the MWG-desired -30/+5 (az/el) direction (30.4 deg off-Sun, so no need for truncation). Future PJ attitudes are preliminary. Cells are highlighted (shaded gray) to point out: before/after ~7 longitude shifts, non-prime shift, weekends, minima/maxima, >4.5 G mag field, opposition/conjunction, SPE ≤ 3.05°, Far EqX distance wrt Galilean satellite orbital ansae, 70-m down times. **MT** = Mountain Time. **PT** = Pacific Time. **DOY** = day of year. **DOY** = day of year. **DOY** = day of year. **OWLT** = one-way light time. **NON** = negative orbit normal. **NTON** = negative tilted orbit normal. **S** = Sun, **P** = Probe, **E** = Earth, **J** = Jupiter in **SPE**, **SEP**, **JPE**, **SJP**. **Xtk** = crosstrack (Juno +Z aligned with Jupiter S pole then tilted 1.5 deg E and 10 deg N for MWR). **EqX** = (outbound) equator crossing. **Far EqX** = inbound equator crossing. Altitudes are Jupiter-detic, and latitudes are Jupiter-centric. Rj = 71,492 km.

From Nav
From SOAP
Formula/Other



# Orbital data useful for science planning [5/8]

Juno Orbital Data (180509 Reference Trajectory)						Time wrt PJ at N Pole (mm:ss)	Jupiter Range at N Pole (Rj)	JPE at N Pole (°)	Max Lat at N Pole (°)				Time wrt PJ at S Pole (mm:ss)	Jupiter Range at S Pole (Rj)	JPE at S Pole (°)	Min Lat at S Pole (°)
Perijove			N Pole (max lat)							S Pole (min lat)						
#	Type	Time (UTC/SCET)	#	Time (UTC/SCET)						#	Time (UTC/SCET)					
0	JOI	07/05/2016 02:47:32	0	07/05/2016 01:52:55	- 54:37	2.04	88.6	89.8	89.8	0	07/05/2016 03:50:17	+ 62:45	2.21	91.4	-89.8	
1	PJ1	08/27/2016 12:50:44	1	08/27/2016 11:58:02	- 52:42	1.97	88.3	89.9	89.9	1	08/27/2016 13:54:42	+ 63:58	2.24	91.7	-89.9	
2	Post-SM	10/19/2016 18:10:54	2	10/19/2016 17:19:24	- 51:30	1.94	87.8	90.0	90.0	2	10/19/2016 19:16:27	+ 65:33	2.28	92.2	-90.0	
3	GRAV	12/11/2016 17:03:41	3	12/11/2016 16:13:25	- 50:16	1.91	87.1	89.8	89.8	3	12/11/2016 18:10:53	+ 67:12	2.32	92.9	-89.8	
4	MWR	02/02/2017 12:57:09	4	02/02/2017 12:07:53	- 49:16	1.89	86.5	89.4	89.4	4	02/02/2017 14:06:15	+ 69:06	2.36	93.5	-89.4	
5	MWR Tilt	03/27/2017 08:51:52	5	03/27/2017 08:04:37	- 47:15	1.84	86.0	89.0	89.0	5	03/27/2017 10:01:32	+ 69:40	2.38	94.0	-89.0	
6	GRAV	05/19/2017 06:00:47	6	05/19/2017 05:14:33	- 46:14	1.82	85.6	88.4	88.4	6	05/19/2017 07:12:24	+ 71:37	2.42	94.3	-88.4	
7	MWR	07/11/2017 01:54:42	7	07/11/2017 01:09:33	- 45:09	1.79	85.2	87.7	87.7	7	07/11/2017 03:08:14	+ 73:32	2.47	94.7	-87.7	
8	GRAV	09/01/2017 21:48:50	8	09/01/2017 21:04:43	- 44:07	1.77	84.7	87.1	87.1	8	09/01/2017 23:04:19	+ 75:29	2.52	95.3	-87.1	
9	MWR Tilt	10/24/2017 17:42:31	9	10/24/2017 16:58:56	- 43:35	1.76	84.1	86.4	86.4	9	10/24/2017 19:00:48	+ 78:17	2.58	95.8	-86.4	
10	GRAV	12/16/2017 17:56:59	10	12/16/2017 17:14:07	- 42:52	1.74	83.8	85.6	85.6	10	12/16/2017 19:17:45	+ 80:46	2.64	96.2	-85.6	
11	GRAV	02/07/2018 13:51:30	11	02/07/2018 13:10:16	- 41:14	1.70	83.5	84.7	84.7	11	02/07/2018 15:13:02	+ 81:32	2.66	96.5	-84.7	
12	-30/+20	04/01/2018 09:45:43	12	04/01/2018 09:05:24	- 40:19	1.68	82.9	83.8	83.8	12	04/01/2018 11:09:25	+ 83:42	2.71	97.1	-83.8	
13	GRAV	05/24/2018 05:39:50	13	05/24/2018 05:00:25	- 39:25	1.66	81.9	83.0	83.0	13	05/24/2018 07:05:47	+ 85:57	2.76	98.0	-83.0	
14	GRAV	07/16/2018 05:17:39	14	07/16/2018 04:39:05	- 38:34	1.64	81.4	82.3	82.3	14	07/16/2018 06:45:54	+ 88:15	2.82	98.6	-82.3	
15	GRAV	09/07/2018 01:11:57	15	09/07/2018 00:34:13	- 37:44	1.62	81.5	81.6	81.6	15	09/07/2018 02:42:35	+ 90:38	2.87	98.4	-81.6	
16	-30/+20	10/29/2018 21:06:17	16	10/29/2018 20:29:22	- 36:55	1.60	82.4	80.9	80.9	16	10/29/2018 22:39:20	+ 93:03	2.93	97.6	-80.9	
17	GRAV	12/21/2018 17:00:27	17	12/21/2018 16:23:07	- 37:20	1.61	83.9	80.3	80.3	17	12/21/2018 18:38:47	+ 98:20	3.04	96.1	-80.3	
18	GRAV	02/12/2019 17:34:16	18	02/12/2019 16:58:48	- 35:28	1.56	85.5	79.8	79.8	18	02/12/2019 19:12:07	+ 97:51	3.04	94.5	-79.9	
19	MWR XTK	04/06/2019 12:14:00	19	04/06/2019 11:37:56	- 36:04	1.59	86.3	79.4	79.4	19	04/06/2019 13:57:52	+ 103:52	3.17	93.7	-79.4	
20	-30/+5	05/29/2019 08:08:14	20	05/29/2019 07:31:26	- 36:48	1.61	85.6	79.1	79.1	20	05/29/2019 09:58:32	+ 110:18	3.30	94.4	-79.1	
21	GRAV	07/21/2019 04:02:44	21	07/21/2019 03:26:03	- 36:41	1.61	84.5	78.9	78.9	21	07/21/2019 05:57:07	+ 114:23	3.38	95.5	-78.9	
22	GRAV	09/12/2019 03:40:47	22	09/12/2019 03:04:41	- 36:06	1.60	84.7	78.8	78.8	22	09/12/2019 05:37:41	+ 116:54	3.44	95.3	-78.9	
23	GRAV	11/03/2019 22:18:14	23	11/03/2019 21:46:14	- 32:00	1.48	86.5	74.2	74.2	23	11/04/2019 00:09:53	+ 111:39	3.35	93.6	-74.2	
24	GRAV	12/26/2019 17:35:57	24	12/26/2019 17:03:19	- 32:38	1.51	89.7	74.3	74.3	24	12/26/2019 19:32:55	+ 116:58	3.46	90.4	-74.3	
25	GRAV	02/17/2020 17:51:42	25	02/17/2020 17:19:45	- 31:57	1.49	92.9	74.4	74.4	25	02/17/2020 19:50:08	+ 118:26	3.49	87.1	-74.4	
26	GRAV	04/10/2020 13:47:11	26	04/10/2020 13:16:27	- 30:44	1.46	95.1	74.6	74.6	26	04/10/2020 15:45:10	+ 117:59	3.49	85.0	-74.7	
27	GRAV	06/02/2020 10:19:47	27	06/02/2020 09:49:28	- 30:19	1.45	95.2	75.0	75.0	27	06/02/2020 12:20:05	+ 120:18	3.54	84.9	-75.1	
28	GRAV	07/25/2020 06:15:14	28	07/25/2020 05:45:21	- 29:53	1.44	93.5	75.5	75.5	28	07/25/2020 08:17:59	+ 122:45	3.59	86.6	-75.5	
29	GRAV	09/16/2020 02:10:43	29	09/16/2020 01:41:17	- 29:26	1.43	92.3	76.0	76.0	29	09/16/2020 04:16:03	+ 125:20	3.65	87.7	-76.1	
30	GRAV	11/08/2020 01:49:34	30	11/08/2020 01:20:34	- 29:00	1.42	93.2	76.7	76.7	30	11/08/2020 03:57:36	+ 128:02	3.71	86.9	-76.7	
31	GRAV	12/30/2020 21:45:08	31	12/30/2020 21:16:36	- 28:32	1.41	95.2	77.4	77.4	31	12/30/2020 23:56:10	+ 131:02	3.77	84.9	-77.4	
32	GRAV	02/21/2021 17:40:27	32	02/21/2021 17:11:34	- 28:53	1.42	97.2	78.3	78.3	32	02/21/2021 19:58:16	+ 137:49	3.91	82.8	-78.3	
33	GRAV	04/15/2021 13:36:23	33	04/15/2021 13:08:46	- 27:37	1.39	98.5	79.2	79.2	33	04/15/2021 15:53:53	+ 137:30	3.91	81.5	-79.2	
34	Extra	06/07/2021 09:32:00	34	06/07/2021 09:04:54	- 27:06	1.38	98.8	80.1	80.1	34	06/07/2021 11:53:13	+ 141:13	3.99	81.2	-80.1	
35	Deorbit	07/30/2021 04:32:45	35	07/30/2021 04:08:27	- 24:18	1.29	97.9	81.0	81.0							

Using [spk\\_ref\\_180429\\_210731\\_180509.bsp](#) (latest reference trajectory) after AJ12. The latest reconstructed trajectories are used for AJ12 and earlier. Data are for PJ (perijove) unless stated otherwise. P19 attitude is in the MWR Tilt direction, but truncated at 35 deg off-Sun (vs. 39.4 deg for MWR Tilt). P12 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). P16 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). P20 attitude is in the MWG-desired -30/+5 (az/el) direction (30.4 deg off-Sun, so no need for truncation). Future PJ attitudes are preliminary. Cells are highlighted (shaded gray) to point out: before/after ~7 longitude shifts, non-prime shift, weekends, minima/maxima, >4.5 G mag field, opposition/conjunction, SPE ≤ 3.05°, Far EqX distance wrt Galilean satellite orbital ansae, 70-m down times. **MT** = Mountain Time. **PT** = Pacific Time. **DOY** = day of year. **DOW** = day of week. **OWLT** = one-way light time. **NON** = negative orbit normal. **NTON** = negative tilted orbit normal. **S** = Sun, **P** = Probe, **E** = Earth, **J** = Jupiter in **SPE**, **SEP**, **JPE**, **SJP**. **Xtk** = crosstrack (Juno +Z aligned with Jupiter S pole then tilted 1.5 deg E and 10 deg N for MWR). **EqX** = (outbound) equator crossing. **Far EqX** = inbound equator crossing. Altitudes are Jupiter-detic, and latitudes are Jupiter-centric. Rj = 71,492 km.

From Nav
From SOAP
Formula/Other

Juno Orbital Data (180509 Reference Trajectory)					AJ-to-AJ Orbit	OWLT	Jupiter	Local	Approx	Sys III		JPE	EJP	SJP	Far Equator Crossing		Time wrt	Jupiter	Local
Perijove			Apojove		Duration	at AJ	Range	Time at AJ	Magnetic	W Long		at AJ	at AJ	at AJ			Next PJ at	Range at	Time at
#	Type	Time (UTC/SCET)	#	Time (UTC/SCET)	(days)	(min)	(Rj)	(hrs)	Lat at AJ	at AJ		at AJ	at AJ	at AJ			Far EqX	Far EqX	Far EqX
									(°)	(°)		(°)	(°)	(°)			(days)	(Rj)	(hrs)
0	JOI	07/05/2016 02:47:32	0	07/31/2016 19:46:02	26.707	51.04	113.36	6.0	-10.5	62.4	7.4	97.1	82.4	89.7	0	08/10/2016 05:44:57	- 17.30	104.36	6.0
1	PJ1	08/27/2016 12:50:44	1	09/23/2016 03:44:48	53.332	53.70	113.08	5.7	-12.6	50.2	0.6	86.3	93.3	93.7	1	10/04/2016 17:19:44	- 15.04	99.19	5.7
2	Post-SM	10/19/2016 18:10:54	2	11/15/2016 05:36:45	53.078	51.54	112.70	5.5	3.6	176.3	6.5	75.3	104.2	97.6	2	11/28/2016 18:31:35	- 12.94	93.23	5.4
3	GRAV	12/11/2016 17:03:41	3	01/07/2017 03:11:30	52.899	45.48	112.52	5.2	-0.5	146.9	10.3	67.7	111.7	101.5	3	01/22/2017 08:58:16	- 11.17	87.27	5.1
4	MWR	02/02/2017 12:57:09	4	02/28/2017 22:55:48	52.822	39.08	112.53	4.9	-15.3	50.7	7.0	67.2	112.1	105.3	4	03/17/2017 20:26:59	- 9.52	80.85	4.9
5	MWR Tilt	03/27/2017 08:51:52	5	04/22/2017 19:14:57	52.847	37.42	112.60	4.7	-14.4	335.5	2.9	73.2	106.1	109.1	5	05/11/2017 01:50:07	- 8.17	74.86	4.6
6	GRAV	05/19/2017 06:00:47	6	06/14/2017 15:58:35	52.864	41.94	112.52	4.4	-5.9	275.2	10.0	76.5	102.9	112.9	6	07/04/2017 01:31:06	- 7.02	69.02	4.3
7	MWR	07/11/2017 01:54:42	7	08/06/2017 11:44:04	52.823	48.58	112.52	4.2	-0.8	179.6	9.6	72.3	107.2	116.5	7	08/26/2017 20:54:38	- 6.04	63.54	4.0
8	GRAV	09/01/2017 21:48:50	8	09/28/2017 07:51:01	52.838	53.10	112.51	3.9	-12.9	97.0	4.0	63.2	116.4	120.1	8	10/19/2017 11:30:48	- 5.26	58.76	3.8
9	MWR Tilt	10/24/2017 17:42:31	9	11/20/2017 05:57:23	52.921	53.17	112.76	3.6	-15.5	86.5	3.4	52.6	127.0	123.7	9	12/12/2017 03:50:47	- 4.59	54.31	3.5
10	GRAV	12/16/2017 17:56:59	10	01/12/2018 03:52:42	52.913	48.58	112.50	3.4	-18.8	69.4	9.2	43.8	135.9	127.1	10	02/03/2018 14:51:07	- 3.96	49.76	3.2
11	GRAV	02/07/2018 13:51:30	11	03/05/2018 23:55:41	52.835	41.67	112.50	3.1	-20.8	344.2	9.7	40.2	139.4	130.5	11	03/28/2018 22:29:54	- 3.47	45.97	2.9
12	-30/+20	04/01/2018 09:45:43	12	04/27/2018 19:36:40	52.820	37.11	112.50	2.9	-7.1	245.7	2.3	43.9	135.6	133.7	12	05/21/2018 04:30:56	- 3.05	42.47	2.7
13	GRAV	05/24/2018 05:39:50	13	06/19/2018 17:31:07	52.913	38.77	112.71	2.6	-6.3	227.9	7.4	49.6	129.8	136.8	13	07/13/2018 12:32:15	- 2.70	39.40	2.4
14	GRAV	07/16/2018 05:17:39	14	08/11/2018 15:18:47	52.908	44.90	112.50	2.4	-6.2	205.9	10.7	49.5	130.1	139.8	14	09/04/2018 15:55:07	- 2.39	36.49	2.1
15	GRAV	09/07/2018 01:11:57	15	10/03/2018 10:59:04	52.820	50.82	112.49	2.1	-17.3	106.9	7.2	43.2	136.4	142.6	15	10/27/2018 18:04:03	- 2.13	33.92	1.8
16	-30/+20	10/29/2018 21:06:17	16	11/25/2018 07:01:53	52.835	53.16	112.47	1.9	-27.0	21.5	0.2	34.6	145.2	145.2	16	12/19/2018 17:57:18	- 1.96	32.19	1.6
17	GRAV	12/21/2018 17:00:27	17	01/17/2019 05:19:30	52.929	50.62	112.75	1.7	-27.8	17.6	7.0	27.2	152.6	147.7	17	02/11/2019 00:02:25	- 1.73	29.74	1.3
18	GRAV	02/12/2019 17:34:16	18	03/11/2019 02:47:52	52.895	44.34	112.39	1.4	-26.4	343.8	10.6	23.8	156.0	149.9	18	04/04/2019 21:24:00	- 1.62	28.45	1.0
19	MWR XTK	04/06/2019 12:14:00	19	05/02/2019 22:17:22	52.812	37.95	112.44	1.2	-11.8	238.3	7.2	24.3	155.5	151.8	19	05/27/2019 19:22:23	- 1.53	27.43	0.8
20	-30/+5	05/29/2019 08:08:14	20	06/24/2019 18:02:00	52.823	36.22	112.42	0.9	-15.3	141.8	2.8	27.9	151.8	153.4	20	07/19/2019 17:42:15	- 1.43	26.23	0.5
21	GRAV	07/21/2019 04:02:44	21	08/16/2019 16:00:28	52.916	40.54	112.63	0.7	-18.3	126.3	10.2	30.4	149.2	154.6	21	09/10/2019 19:46:47	- 1.33	25.00	0.2
22	GRAV	09/12/2019 03:40:47	22	10/08/2019 12:50:27	52.868	47.08	112.41	0.4	-28.1	69.5	9.8	28.4	151.3	155.2	22	11/02/2019 20:34:44	- 1.07	21.74	23.8
23	GRAV	11/03/2019 22:18:14	23	11/30/2019 07:39:02	52.784	51.49	112.42	0.2	-23.2	299.0	4.0	25.1	154.7	155.4	23	12/25/2019 16:32:55	- 1.04	21.34	23.6
24	GRAV	12/26/2019 17:35:57	24	01/22/2020 05:43:13	52.920	51.41	112.72	23.9	-21.6	286.7	3.7	25.0	154.8	155.2	24	02/16/2020 18:17:24	- 0.98	20.50	23.3
25	GRAV	02/17/2020 17:51:42	25	03/15/2020 03:44:25	52.918	46.76	112.48	23.7	-19.9	272.6	9.7	28.6	151.1	154.3	25	04/09/2020 16:01:02	- 0.91	19.45	23.1
26	GRAV	04/10/2020 13:47:11	26	05/07/2020 00:15:53	52.855	39.90	112.51	23.4	-14.4	204.3	10.5	31.2	148.5	153.0	26	06/01/2020 13:42:56	- 0.86	18.75	22.8
27	GRAV	06/02/2020 10:19:47	27	06/28/2020 20:24:30	52.839	35.15	112.49	23.2	-22.5	122.2	3.2	29.7	149.9	151.3	27	07/24/2020 10:45:13	- 0.81	18.06	22.6
28	GRAV	07/25/2020 06:15:14	28	08/20/2020 16:08:29	52.822	36.36	112.48	22.9	-34.7	25.2	7.2	27.6	152.1	149.2	28	09/15/2020 07:44:08	- 0.77	17.39	22.3
29	GRAV	09/16/2020 02:10:43	29	10/12/2020 14:05:37	52.915	42.32	112.70	22.6	-35.1	8.6	11.1	28.1	151.6	146.8	29	11/07/2020 08:21:17	- 0.73	16.77	22.1
30	GRAV	11/08/2020 01:49:34	30	12/04/2020 11:36:41	52.897	48.34	112.50	22.4	-32.9	336.4	7.6	31.5	148.3	144.2	30	12/30/2020 05:15:58	- 0.69	16.12	21.8
31	GRAV	12/30/2020 21:45:08	31	01/26/2021 07:35:46	52.833	50.84	112.48	22.1	-20.4	248.5	0.4	38.2	141.5	141.3	31	02/21/2021 01:41:13	- 0.67	15.77	21.6
32	GRAV	02/21/2021 17:40:27	32	03/20/2021 03:47:12	52.841	48.59	112.50	21.8	-19.8	168.2	7.1	46.5	133.1	138.2	32	04/14/2021 22:54:13	- 0.61	14.91	21.3
33	GRAV	04/15/2021 13:36:23	33	05/11/2021 23:30:28	52.822	42.68	112.51	21.6	-34.7	70.9	11.3	53.1	126.4	135.0	33	06/06/2021 19:41:32	- 0.58	14.30	21.1
34	Extra	06/07/2021 09:32:00	34	07/03/2021 19:26:51	52.831	36.20	112.49	21.3	-36.5	341.5	8.7	54.4	125.0	131.7	34	07/29/2021 16:32:53	- 0.50	13.01	20.8
35	Deorbit	07/30/2021 04:32:45																	

Using [spk\\_ref\\_180429\\_210731\\_180509.bsp](#) (latest reference trajectory) after AJ12. The latest reconstructed trajectories are used for AJ12 and earlier. Data are for PJ (perijove) unless stated otherwise.

PJ9 attitude is in the MWR Tilt direction, but truncated at 35 deg off-Sun (vs. 39.4 deg for MWR Tilt). PJ12 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). PJ16 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). PJ20 attitude is in the MWG-desired -30/+5 (az/el) direction (30.4 deg off-Sun, so no need for truncation). Future PJ attitudes are preliminary. Cells are highlighted (shaded gray) to point out: before/after ~7 longitude shifts, non-prime shift, weekends, minima/maxima, >4.5 G mag field, opposition/conjunction, SPE ≤ 3.05°, Far EqX distance wrt Galilean satellite orbital ansae, 70-m down times.

**MT** = Mountain Time. **PT** = Pacific Time. **DOY** = day of year. **DOW** = day of week. **OWLT** = one-way light time. **NON** = negative orbit normal. **NTON** = negative tilted orbit normal. **S** = Sun, **P** = Probe, **E** = Earth, **J** = Jupiter in **SPE**, **SEP**, **JPE**, **SJP**. **Xtk** = crosstrack (Juno +Z aligned with Jupiter S pole then tilted 1.5 deg E and 10 deg N for MWR). **EqX** = (outbound) equator crossing. **Far EqX** = inbound equator crossing. Altitudes are Jupiter-detic, and latitudes are Jupiter-centric. Rj = 71,492 km.

From Nav
From SOAP
Formula/Other



# Orbital data useful for science planning [7/8]

Juno Orbital Data (180509 Reference Trajectory)			Orbit (PJ-1d to PJ-1d, start time truncated to the previous hour)		Orbit Duration (days)	First Seq #	D/L Rate to BWG (bps)	D/L Rate to HEF (bps)	D/L Rate to SBW (bps)	D/L Rate to 70-m (bps)	Total D/L Capability (Gb/Orbit)	Science D/L Capability (Gb/Orbit)	DSS Down Times (orbit)	DSS Down Times (PJ/OTM)
#	Type	Time (UTC/SCET)	#	Start (UTC/SCET)										
0	JOI	07/05/2016 02:47:32					22000	26000	30000	120000			63	ok
1	PJ1	08/27/2016 12:50:44				jm0003	18000	22000	26000	120000	108.2	80.5	63	ok
2	Post-SM	10/19/2016 18:10:54	2	10/18/2016 18:00	52.958	jm0005	18000	18000	18000	50000			ok	ok
3	GRAV	12/11/2016 17:03:41	3	12/10/2016 17:00	52.792	jm0031	26000	22000	26000	120000	93.8	66.5	14	ok
4	MWR	02/02/2017 12:57:09	4	02/01/2017 12:00	52.833	jm0041	35000	30000	35000	150000	141.7	102.6	14,43	14
5	MWR Tilt	03/27/2017 08:51:52	5	03/26/2017 08:00	52.917	jm0051	40000	40000	50000	200000	137.0	99.3	63,25	63
6	GRAV	05/19/2017 06:00:47	6	05/18/2017 06:00	52.792	jm0061	40000	40000	40000	200000	155.2	112.7	14	ok
7	MWR	07/11/2017 01:54:42	7	07/10/2017 01:00	52.833	jm0071	26000	30000	35000	150000	106.6	76.0	14	14
8	GRAV	09/01/2017 21:48:50	8	08/31/2017 21:00	52.833	jm0081	22000	22000	26000	120000	67.5	46.4	43	ok
9	MWR Tilt	10/24/2017 17:42:31	9	10/23/2017 17:00	53.000	jm0091	18000	18000	18000	50000	63.4	43.3	43	43
10	GRAV	12/16/2017 17:56:59	10	12/15/2017 17:00	52.833	jm0101	22000	22000	22000	100000	83.9	58.6	43	43
11	GRAV	02/07/2018 13:51:30	11	02/06/2018 13:00	52.833	jm0111	30000	26000	30000	150000	112.0	79.9	43,25,14,63	43
12	-30/+20	04/01/2018 09:45:43	12	03/31/2018 09:00	52.833	jm0121	40000	40000	40000	200000	133.7	96.6	25,63	25,63
13	GRAV	05/24/2018 05:39:50	13	05/23/2018 05:00	53.000	jm0131	40000	40000	50000	200000	143.1	103.7	25,63	25,63
14	GRAV	07/16/2018 05:17:39	14	07/15/2018 05:00	52.833	jm0141	30000	35000	40000	200000	106.2	75.6	63,25	63
15	GRAV	09/07/2018 01:11:57	15	09/06/2018 01:00	52.833	jm0151	26000	26000	30000	120000	75.5	52.4	63,43,14	63
16	-30/+20	10/29/2018 21:06:17	16	10/28/2018 21:00	52.833	jm0161	22000	18000	22000	50000	53.3	35.7	ok	ok
17	GRAV	12/21/2018 17:00:27	17	12/20/2018 17:00	53.000	jm0171	22000	18000	22000	50000	83.3	58.1	ok	ok
18	GRAV	02/12/2019 17:34:16	18	02/11/2019 17:00	52.792	jm0181	26000	22000	30000	100000	97.0	68.6	43	ok
19	MWR Xtk	04/06/2019 12:14:00	19	04/05/2019 12:00	52.833	jm0191	35000	35000	40000	150000	124.5	89.6	14,63	ok
20	-30/+5	05/29/2019 08:08:14	20	05/28/2019 08:00	52.833	jm0201	40000	50000	50000	200000	125.9	90.7	63	63
21	GRAV	07/21/2019 04:02:44	21	07/20/2019 04:00	52.958	jm0211	40000	40000	50000	200000	128.4	92.5	63,25	63
22	GRAV	09/12/2019 03:40:47	22	09/11/2019 03:00	52.792	jm0221	30000	30000	35000	120000	138.4	99.0	ok	ok
23	GRAV	11/03/2019 22:18:14	23	11/02/2019 22:00	52.792	jm0231	22000	22000	26000	100000	76.3	53.1	ok	ok
24	GRAV	12/26/2019 17:35:57	24	12/25/2019 17:00	53.000	jm0241	1000	1000	1000	18000	64.4	44.2	14,43	ok
25	GRAV	02/17/2020 17:51:42	25	02/16/2020 17:00	52.833	jm0251	22000	22000	26000	100000	93.7	66.0	43	43
26	GRAV	04/10/2020 13:47:11	26	04/09/2020 13:00	52.875	jm0261	30000	30000	35000	120000	117.2	84.0	43	43
27	GRAV	06/02/2020 10:19:47	27	06/01/2020 10:00	52.833	jm0271	40000	40000	50000	150000	141.0	102.0	43	43
28	GRAV	07/25/2020 06:15:14	28	07/24/2020 06:00	52.833	jm0281	50000	50000	50000	200000	134.8	97.3	43	43
29	GRAV	09/16/2020 02:10:43	29	09/15/2020 02:00	52.958	jm0291	40000	40000	50000	150000	110.1	78.6	43,25,63	43
30	GRAV	11/08/2020 01:49:34	30	11/07/2020 01:00	52.833	jm0301	30000	26000	30000	120000	78.3	54.5	63	63
31	GRAV	12/30/2020 21:45:08	31	12/29/2020 21:00	52.833	jm0311	22000	22000	26000	100000	66.2	45.6	14	ok
32	GRAV	02/21/2021 17:40:27	32	02/20/2021 17:00	52.833	jm0321	22000	22000	26000	100000	78.5	54.6	63	ok
33	GRAV	04/15/2021 13:36:23	33	04/14/2021 13:00	52.833	jm0331	30000	30000	30000	120000	103.6	73.6	63	63
34	Extra	06/07/2021 09:32:00	34	06/06/2021 09:00	52.792	jm0341	40000	40000	50000	150000	141.4	102.4	63	63
35	Deorbit	07/30/2021 04:32:45	35	07/29/2021 04:00	1.023	jm0351	50000	50000	50000	200000			63	63

Total Data Return Capability (Gb), Orbits 1 + 3-33 = **3343** **2382**

Using [spk\\_ref\\_180429\\_210731\\_180509.bsp](#) (latest reference trajectory) after AJ12. The latest reconstructed trajectories are used for AJ12 and earlier. Data are for PJ (peri-jove) unless stated otherwise.

PJ9 attitude is in the MWR Tilt direction, but truncated at 35 deg off-Sun (vs. 39.4 deg for MWR Tilt). PJ12 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg).

PJ16 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). PJ20 attitude is in the MWG-desired -30/+5 (az/el) direction (30.4 deg off-Sun, so no need for truncation). Future PJ attitudes are preliminary. Cells are highlighted (shaded gray) to point out: before/after ~7 longitude shifts, non-prime shift, weekends, minima/maxima, >4.5 G mag field, opposition/conjunction, SPE ≤ 3.05°, Far EqX distance wrt Galilean satellite orbital ansae, 70-m down times.

MT = Mountain Time. PT = Pacific Time. DOY = day of year. DOW = day of week. OWLT = one-way light time. NON = negative orbit normal. NTON = negative tilted orbit normal. S = Sun, P = Probe, E = Earth, J = Jupiter in SPE, SEP, JPE, SJP. Xtk = crosstrack (Juno +Z aligned with Jupiter S pole then tilted 1.5 deg E and 10 deg N for MWR). EqX = (outbound) equator crossing. Far EqX = inbound equator crossing. Altitudes are Jupiter-detic, and latitudes are Jupiter-centric. Rj = 71,492 km.

From Nav
From SOAP
Formula/Other



# Orbital data useful for science planning [8/8]

Juno Orbital Data (180509 Reference Trajectory)			PJ Time (ERT) wrt DSS-25 Max Elevation (hh:mm)	Uplink (ERT) wrt DSS-25 10° Rise (hh:mm)	PJ ΔV Det (m/s)	AJ ΔV Det (m/s)	OTM Start wrt PJ (hh:mm)	Sub-Earth Jupiter Latitude (°)	Sub-Earth Jupiter Sys III W Long (°)	Jupiter RA wrt Earth (°)	Sub-Jupiter Earth W Longitude (°)	Sun Latitude at Jupiter (°)
#	Type	Time (UTC/SCET)										
0	JOI	07/05/2016 02:47:32	03:25	04:16	546.6			-1.6	134.6	169.1	156.4	-2.00
1	PJ1	08/27/2016 12:50:44	-07:28	-06:58	0.6			-1.8	188.0	177.9	351.0	-2.16
2	Post-SM	10/19/2016 18:10:54	00:37	00:54	2.6		~6 days	-2.2	68.6	188.4	113.0	-2.32
3	GRAV	12/11/2016 17:03:41	02:18	02:32	1.2		07:30	-2.7	76.5	197.6	139.2	-2.46
4	MWR	02/02/2017 12:57:09	01:15	01:38	0.3	3.8	07:30	-3.0	341.3	201.9	125.3	-2.58
5	MWR Tilt	03/27/2017 08:51:52	00:46	01:22	1.8		07:30	-3.0	254.9	198.8	119.2	-2.70
6	GRAV	05/19/2017 06:00:47	01:46	02:27	2.8	1.1	07:30	-2.8	215.7	193.4	134.0	-2.80
7	MWR	07/11/2017 01:54:42	01:13	01:39	2.8	1.1	07:30	-2.6	124.5	194.0	123.9	-2.89
8	GRAV	09/01/2017 21:48:50	00:13	00:19	0.9		07:30	-2.6	26.8	200.9	107.6	-2.97
9	MWR Tilt	10/24/2017 17:42:31	-01:02	-01:15	3.6		~9 days	-2.8	285.4	211.2	87.7	-3.03
10	GRAV	12/16/2017 17:56:59	01:54	01:34	0.6	5.4	07:30	-3.1	341.4	222.1	132.8	-3.07
11	GRAV	02/07/2018 13:51:30	00:40	00:25	3.4	3.4	07:30	-3.3	243.7	229.8	115.8	-3.10
12	-30/+20	04/01/2018 09:45:43	-00:05	-00:07	2.0	3.8	07:30	-3.4	153.0	230.3	105.8	-3.12
13	GRAV	05/24/2018 05:39:50	-00:21	-00:14	3.2	4.5	07:30	-3.3	68.7	224.4	102.4	-3.12
14	GRAV	07/16/2018 05:17:39	03:02	03:02	4.7	4.7	07:30	-3.1	116.8	221.3	152.2	-3.10
15	GRAV	09/07/2018 01:11:57	02:13	01:54	2.0	5.1	07:30	-2.9	22.0	225.8	138.3	-3.07
16	-30/+20	10/29/2018 21:06:17	01:00	00:23	2.0		07:30	-2.9	282.0	235.8	118.9	-3.02
17	GRAV	12/21/2018 17:00:27	-00:25	-01:11	1.5	12.2	07:30	-2.9	180.1	248.0	97.3	-2.96
18	GRAV	02/12/2019 17:34:16	02:48	02:07	0.3	0.0	07:30	-2.8	248.9	258.8	147.2	-2.88
19	MWR Xtk	04/06/2019 12:14:00	00:29	00:00	0.8	0.0	07:30	-2.8	109.0	263.9	114.2	-2.78
20	-30/+5	05/29/2019 08:08:14	00:01	-00:17	1.7	4.3	07:30	-2.8	22.2	260.3	108.4	-2.67
21	GRAV	07/21/2019 04:02:44	-00:08	-00:29	3.0	7.3	07:30	-2.7	298.0	254.0	105.3	-2.55
22	GRAV	09/12/2019 03:40:47	03:00	02:27	1.9	56.2	07:30	-2.5	342.3	254.8	151.2	-2.41
23	GRAV	11/03/2019 22:18:14	00:38	-00:10	0.0	0.0	07:30	-2.3	197.8	263.4	114.0	-2.25
24	GRAV	12/26/2019 17:35:57	-01:23	-02:17		8.6	~AJ24-4d	-2.1	74.0	276.0	83.0	-2.08
25	GRAV	02/17/2020 17:51:42	01:27	00:42	3.6	11.2	07:30	-1.7	130.2	288.6	126.5	-1.90
26	GRAV	04/10/2020 13:47:11	00:09	-00:17	0.9	6.8	07:30	-1.4	32.5	297.5	108.6	-1.70
27	GRAV	06/02/2020 10:19:47	-00:00	-00:14	0.4	6.3	07:30	-1.3	324.4	298.8	107.5	-1.50
28	GRAV	07/25/2020 06:15:14	-00:14	-00:29	3.1	5.8	07:30	-1.3	240.7	292.7	104.5	-1.28
29	GRAV	09/16/2020 02:10:43	-00:31	-00:57	4.8	5.8	07:30	-1.3	154.8	288.9	99.2	-1.05
30	GRAV	11/08/2020 01:49:34	02:22	01:46	0.4	5.3	07:30	-1.1	195.7	294.0	141.2	-0.82
31	GRAV	12/30/2020 21:45:08	01:06	00:30	0.6		07:30	-0.8	95.9	304.9	121.1	-0.58
32	GRAV	02/21/2021 17:40:27	-00:19	-00:44	4.5	9.3	07:30	-0.3	354.0	317.6	99.4	-0.33
33	GRAV	04/15/2021 13:36:23	-01:43	-01:46	1.7	3.9	07:30	0.2	253.9	328.4	79.6	-0.08
34	Extra	06/07/2021 09:32:00	-02:48	-02:32		19.2		0.7	158.6	334.2	64.8	0.17
35	Deorbit	07/30/2021 04:32:45	-04:17	-03:54				0.8	38.2	332.3	43.9	0.43

<--- Latest reference trajectory

Using [spk\\_ref\\_180429\\_210731\\_180509.bsp](#) (latest reference trajectory) after AJ12. The latest reconstructed trajectories are used for AJ12 and earlier. Data are for PJ (peri-jove) unless stated otherwise.  
 P19 attitude is in the MWR Tilt direction, but truncated at 35 deg off-Sun (vs. 39.4 deg for MWR Tilt). P12 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg).  
 P16 attitude is in the MWG-desired -30/+20 (az/el) direction, but truncated at 35 deg off-Sun (vs. 35.5 deg). P20 attitude is in the MWG-desired -30/+5 (az/el) direction (30.4 deg off-Sun, so no need for truncation). Future PJ attitudes are preliminary.  
 Cells are highlighted (shaded gray) to point out: before/after ~7 longitude shifts, non-prime shift, weekends, minima/maxima, >4.5 G mag field, opposition/conjunction, SPE ≤ 3.05°, Far EqX distance wrt Galilean satellite orbital ansae, 70-m down times.  
**MT** = Mountain Time. **PT** = Pacific Time. **DOY** = day of year. **DOW** = day of week. **OWL** = one-way light time. **NON** = negative orbit normal. **NTON** = negative tilted orbit normal. **S** = Sun, **P** = Probe, **E** = Earth, **J** = Jupiter in **SPE**, **SEP**, **JPE**, **SJP**.  
**Xtk** = crosstrack (Juno +Z aligned with Jupiter S pole then tilted 1.5 deg E and 10 deg N for MWR). **EqX** = (outbound) equator crossing. **Far EqX** = inbound equator crossing. Altitudes are Jupiter-detic, and latitudes are Jupiter-centric. R<sub>J</sub> = 71,492 km.

From Nav
From SOAP
Formula/Other

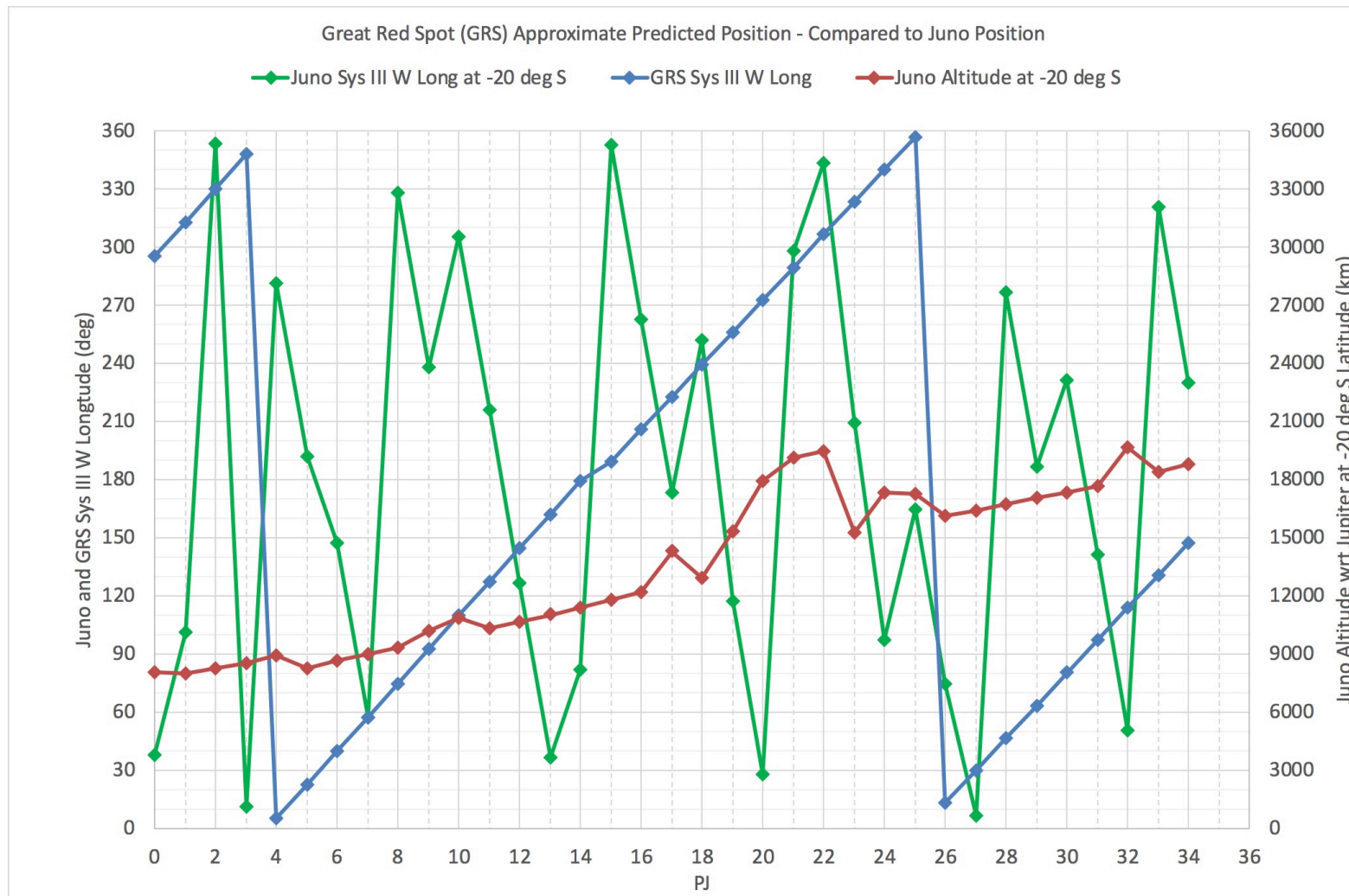


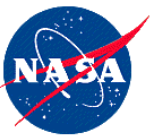
# Great Red Spot predicts (tentative, based on recent Earth-based observations) [1/2]

- From Orbital Data Useful for Science Planning – data on slide 20. See plot on next slide.
- More **explanation of latest Great Red Spot predicts** (bullets refer to data on slide 20):
  - Altitude wrt Jupiter at -20 deg S assumes -20 deg S is Jupiter-centric latitude.
  - Juno System III W longitude at -20 deg S latitude is now accurately calculated (I had previously approximated it to be longitude at EqX + 6 deg, but that was too rough – I now realize it can differ from longitude at EqX by +5 to +12 deg).
  - GRS Sys III W longitude and uncertainty ( $\sigma$ ) are updated  $\geq$  PJ15 with a reference position = 183.1 deg Sys III W longitude on 8/18/18 12:00 UTC, and drift rate =  $+9.5 \pm 0.4$  deg per 30 days, based on latest info from John Rogers and the JUPOS amateur community. He provided the reference position, and I averaged his estimates of  $\sim 9.0$  to  $10.0$  deg per 30 days. (I previously used  $9.9 \pm 0.4$  deg per 30 days.) Understandably, he is reluctant to be more specific, but I wanted to provide predicts, albeit with caveats.
  - Juno wrt GRS longitude is updated based on values in previous 2 columns (slide 20).
    - PJ18 estimate is now Juno longitude wrt GRS  $\sim 13$  deg, and PJ21 is now  $\sim 8$  deg (PJ18 was  $\sim 0$  deg, PJ21 was  $\sim 8$  deg) – Gravity Science still hopes to use these PJs.
- We swapped PJ23 longitude with PJ18 to get a more favorable GRS flyover opportunity at PJ18 (mainly for Gravity Science), but it may turn out not so favorable after all. PJ18 S/C longitude will be 252 deg W (at -20 deg S), but John Rogers (9/20-21) suggests a probable range for GRS longitude is 234-243 deg W. The GRS is 15 deg long, so the implication is we could be near the west end of the GRS, or we could be  $\sim 10$  deg further west of it.

# Great Red Spot predicts (tentative, based on recent Earth-based observations) [2/2]

- GRS predicts (from Orbital Data Useful for Science Planning – see data on slide 20):

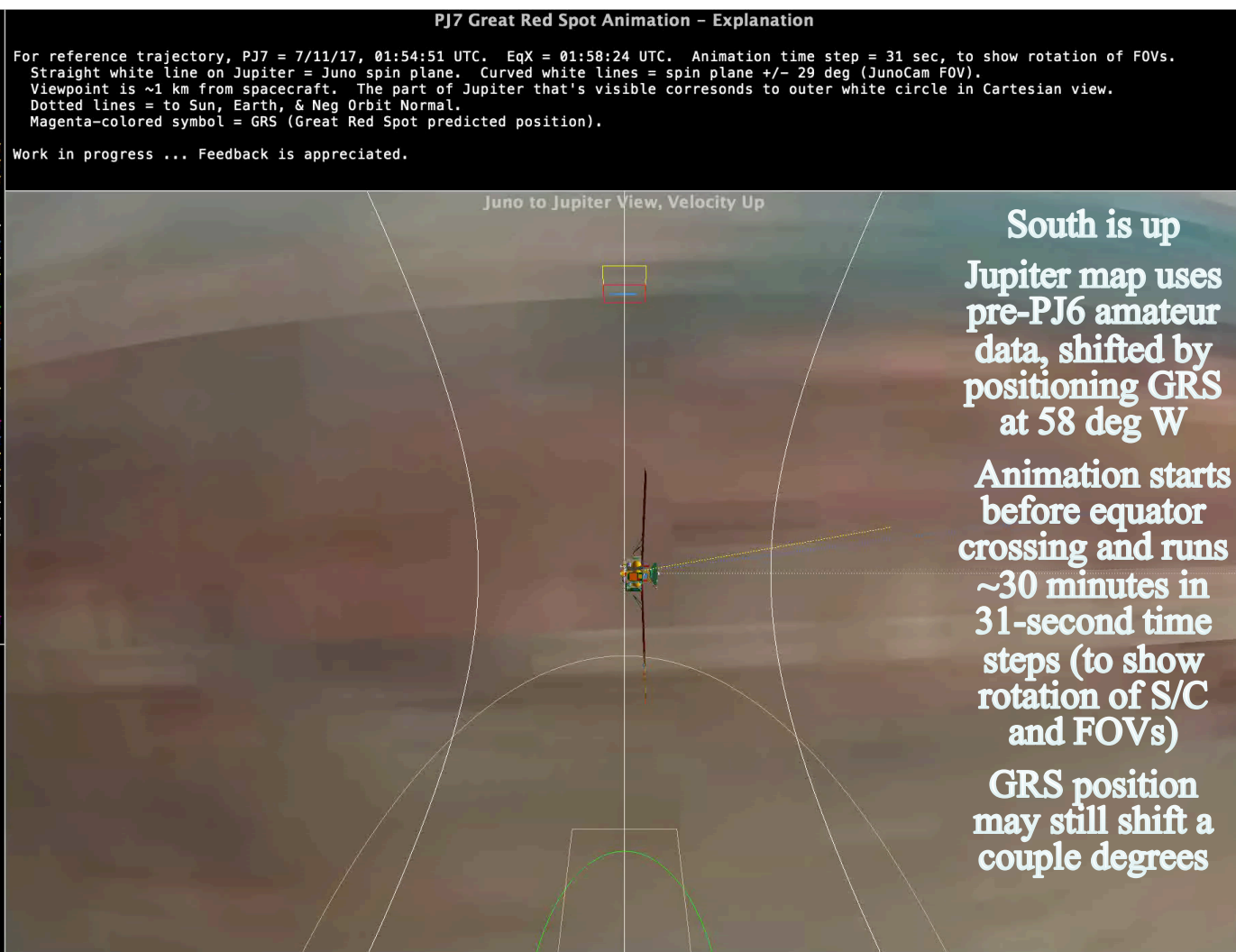
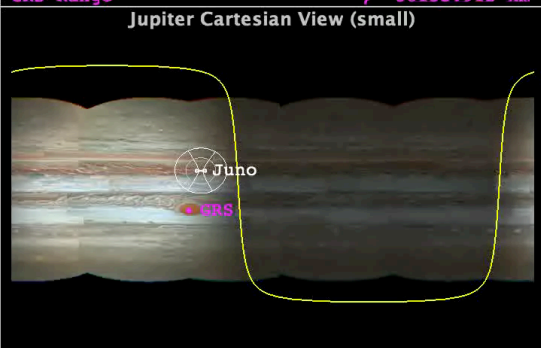




# PJ7 animation of Great Red Spot flyover

Activity Period Data (Juno time)  
2017/07/11 01:54:51.0000 UTC

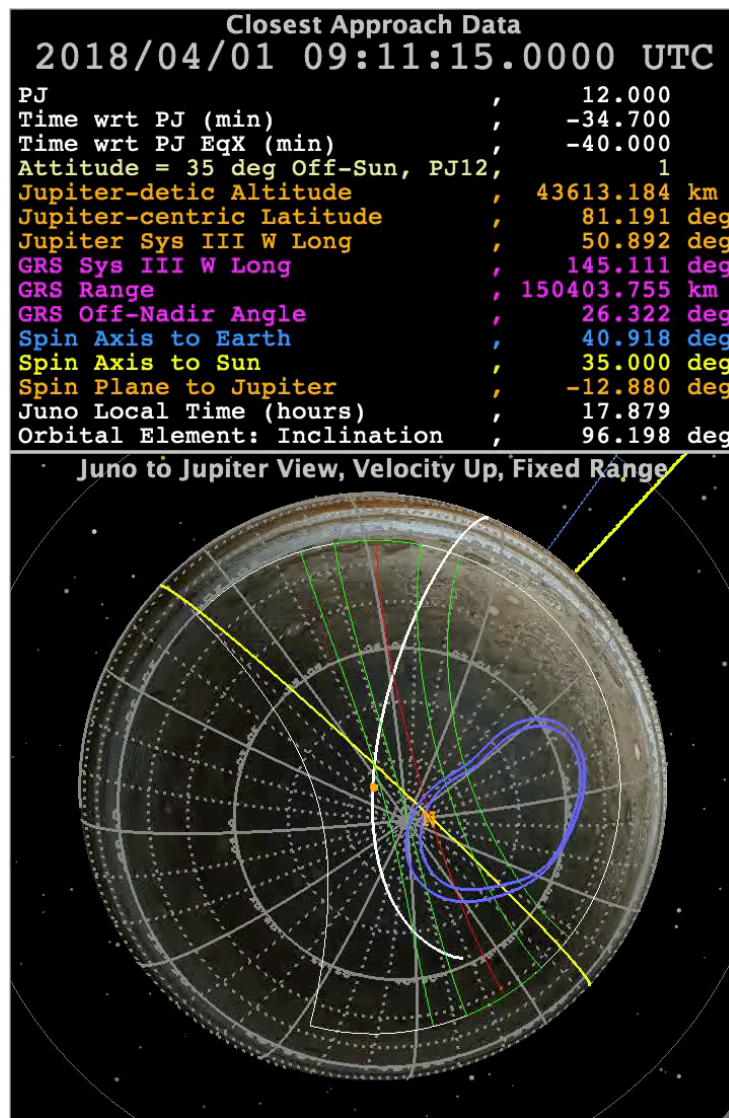
DOY (UTC)	192.000
PJ	7.000
Time wrt PJ (min)	0.000
Time wrt PJ+1 (days)	-52.829
Jupiter Range (Rj)	1.047
Jupiter Diameter	145.520 deg
Jupiter-centric Latitude	9.430 deg
Jupiter Sys III W Long	49.482 deg
OWLT (min)	45.185
Earth Range (AU)	5.433
SPE	10.717 deg
SEP	85.666 deg
JPE	104.189 deg
SJP	65.350 deg
Attitude = MWR	1
Goldstone Elevation	49.424 deg
Canberra Elevation	5.047 deg
Madrid Elevation	-25.338 deg
Jupiter-detic Altitude	3499.591 km
Juno Jovicentric Speed (km/s)	58.096
Jupiter Mag Dipole Latitude	0.895 deg
Sun Range (AU)	5.451
GRS Sys III W Long	57.891 deg
Spin Axis to Earth	15.959 deg
Spin Axis to Sun	26.435 deg
Spin Axis to Jupiter	90.000 deg
Jup Near-Limb Spin Axis Angle	17.240 deg
Jup Far-Limb Spin Axis Angle	162.760 deg
Jup Near-Limb Spin Plane Angle	-72.760 deg
Jup Far-Limb Spin Plane Angle	72.760 deg
JunoCam Jupiter Res (# pixels)	4014.355
JunoCam Jupiter Res (km/pixel)	2.214 km
JIRAM Jupiter Res (# pixels)	10477.457
JIRAM Jupiter Res (km/pixel)	0.848 km
GRS Off-Nadir Angle	67.986 deg
GRS Range	38152.912 km



- This **PJ7 animation** was made before May 2017 Science Team Meeting (pre-PJ7)

# PJ12 animation of Great Red Spot near-flyover

- This **PJ12 animation** (of GRS near-flyover) was made as we planned this off-Sun attitude, -30/+20 (az/el) limited to 35 deg off-Sun
- Showing Jupiter at fixed range, with Juno's velocity direction (south) up
- Main purpose was to show what we would see using the 35 deg off-Sun -30/+20 attitude:
  - JunoCam FOV = white butterfly shape (what it sees during one spin), and spin plane = red curve bisecting JunoCam FOV
  - MWR FOVs (A1 ~22-deg & A3 ~12-deg beamwidth) = long green shapes (horizon to horizon) centered on JunoCam FOV
  - Bold white curve = S/C ground track (red spin plane curve roughly follows bold white ground track near PJ or equator crossing, which is what MWR intends)
- MWR does not appear to get good views of the GRS, but JunoCam sees it at an angle





# Backup

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- Nav summary of 180509 reference trajectory (6 pages)
- Terminology – Numbering for perijoves, apojooves, orbits, and sequences
- Solar conjunctions (including near AJ16 and PJ24)
- Perijove attitudes (more explanations, including 8 pages from Marty Brennan)
- Additional attitude (SPICE C-kernel) information
- Stacked linear timelines (info for all orbits on 1 page, 13 pages from Marty Brennan)
- Maneuver strategy
- Eclipse geometry and eclipse avoidance strategy
- Radiation accumulation vs. perijove (from Nav), and orbital radiation environment



# Nav 180509 reference trajectory [1/6]

## Overview of current reference trajectory

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- Previously released reference trajectory: 171109
  - Based on OD241\_v1 (post-OTM-09)
  - Used de436 planetary ephemeris and jup310 satellite ephemeris
- New reference trajectory update: **180509** (spk\_ref\_180429\_210731\_180509.bsp)
  - On NAIF public server: <https://naif.jpl.nasa.gov/pub/naif/JUNO/kernels/spk/>
  - Based on OD273\_v1 (post-APO-12)
  - Swaps PJ18 and PJ23 longitudes to create GRS flyover opportunity at PJ18
    - Total mission impulsive  $\Delta V$  reduced by 0.9 m/s
  - Uses de438 planetary ephemeris and jup310 satellite ephemeris



# Nav 180509 reference trajectory [2/6] Summary

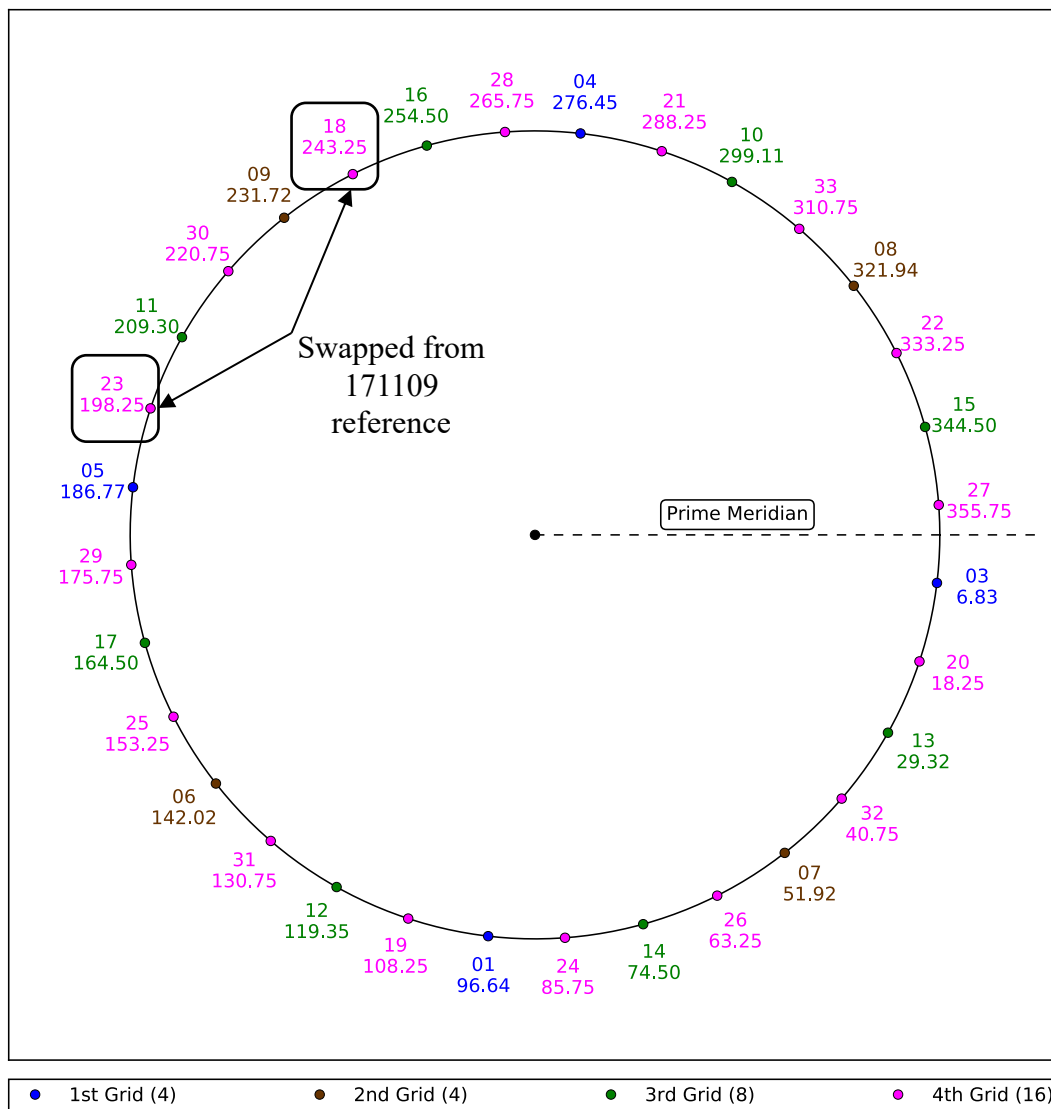
Note that UTC is 00:01:08  
or 00:01:09 earlier than ET

## Perijove and Equator Crossing Characteristics

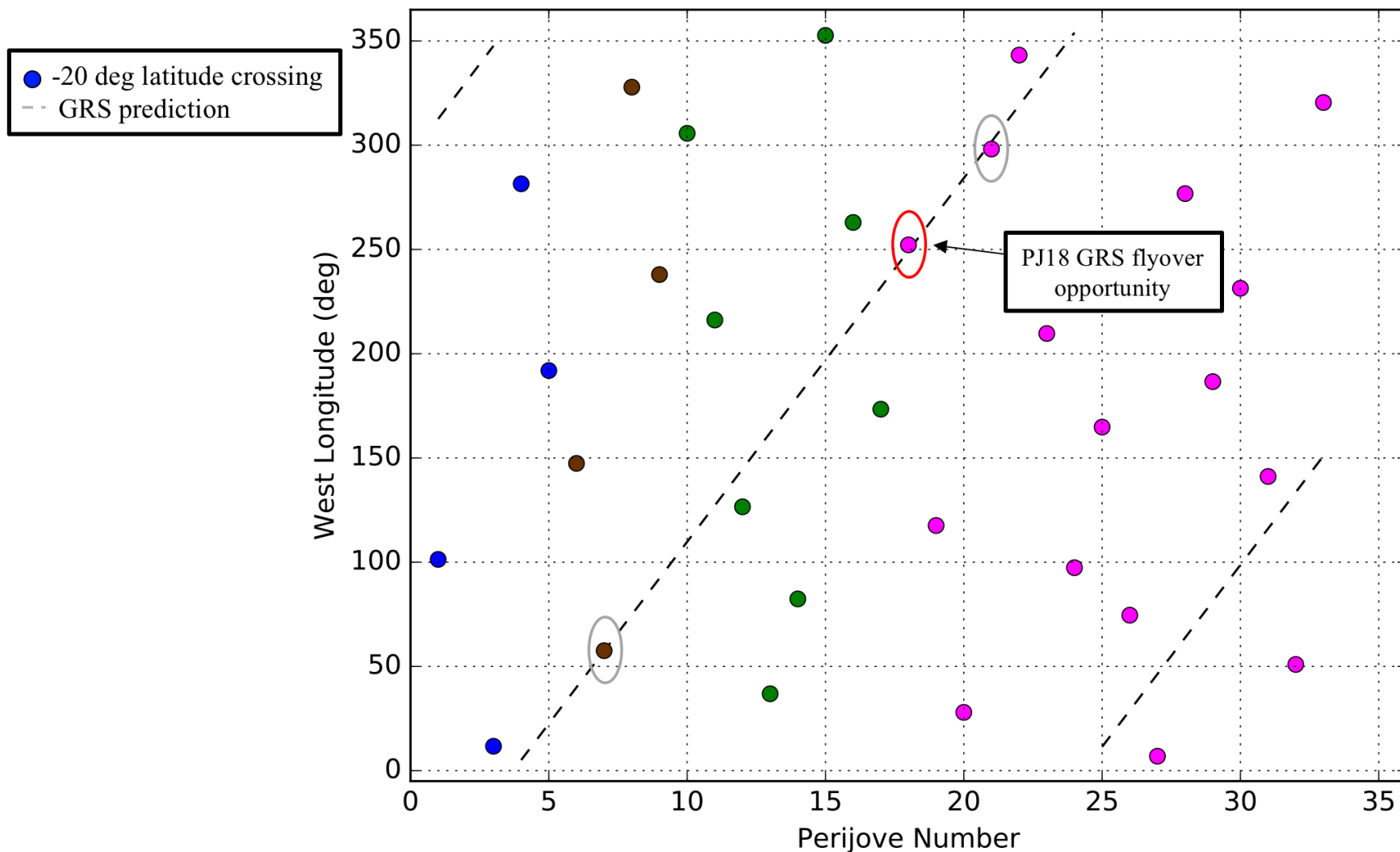
Orbit #	PJ Epoch (ET)	SEP (deg)	Obl. Alt. (km)	Lat. (deg)	Vel.(I) (km/s)	Inc. (deg)	Eq-X Epoch (ET)	Eq-X Lon. (deg)
13	24-MAY-2018 05:40:59	163.39	3497.83	14.84	58.15	96.96	24-MAY-2018 05:46:38	29.32
14	16-JUL-2018 05:18:48	109.73	3500.00	15.70	58.16	97.68	16-JUL-2018 05:24:47	74.50
15	07-SEP-2018 01:13:06	63.65	3500.00	16.56	58.17	98.36	07-SEP-2018 01:19:25	344.50
16	29-OCT-2018 21:07:26	21.53	3500.00	17.39	58.18	99.01	29-OCT-2018 21:14:06	254.50
17	21-DEC-2018 17:01:36	20.21	5051.39	18.15	57.58	99.60	21-DEC-2018 17:08:47	164.50
18	12-FEB-2019 17:35:24	64.03	3500.00	18.95	58.20	100.08	12-FEB-2019 17:42:42	243.25
19	06-APR-2019 12:15:08	112.09	5296.38	19.67	57.51	100.53	06-APR-2019 12:23:01	108.25
20	29-MAY-2019 08:09:23	166.67	7240.42	20.34	56.79	100.85	29-MAY-2019 08:17:51	18.25
21	21-JUL-2019 04:03:53	137.05	7975.00	21.00	56.52	101.05	21-JUL-2019 04:12:46	288.25
22	12-SEP-2019 03:41:55	86.89	7975.00	21.66	56.54	101.09	12-SEP-2019 03:51:06	333.25
23	03-NOV-2019 22:19:23	42.73	3500.00	22.46	58.26	105.71	03-NOV-2019 22:28:17	198.25
24	26-DEC-2019 17:37:05	0.82	5035.92	22.93	57.66	105.62	26-DEC-2019 17:46:28	85.75
25	17-FEB-2020 17:52:51	41.34	4700.00	23.48	57.80	105.49	17-FEB-2020 18:02:23	153.25
26	10-APR-2020 13:48:20	85.68	3500.00	24.08	58.28	105.25	10-APR-2020 13:57:53	63.25
27	02-JUN-2020 10:20:55	135.66	3500.00	24.67	58.29	104.85	02-JUN-2020 10:30:41	355.75
28	25-JUL-2020 06:16:23	168.16	3500.00	25.29	58.30	104.39	25-JUL-2020 06:26:23	265.75
29	16-SEP-2020 02:11:52	113.74	3500.00	25.92	58.32	103.87	16-SEP-2020 02:22:06	175.75
30	08-NOV-2020 01:50:42	65.98	3500.00	26.58	58.33	103.24	08-NOV-2020 02:01:11	220.75
31	30-DEC-2020 21:46:16	22.88	3500.00	27.28	58.34	102.53	30-DEC-2020 21:57:00	130.75
32	21-FEB-2021 17:41:35	18.38	4884.12	27.98	57.81	101.63	21-FEB-2021 17:52:53	40.75
33	15-APR-2021 13:37:31	59.89	3500.00	28.76	58.37	100.76	15-APR-2021 13:48:47	310.75
34	07-JUN-2021 09:33:09	104.96	3500.00	29.55	58.38	99.86	07-JUN-2021 09:44:41	220.75
35	30-JUL-2021 04:33:54	157.41	-700.00	30.46	60.16	98.95	30-JUL-2021 04:44:46	97.00

0.82 SEP < 5°

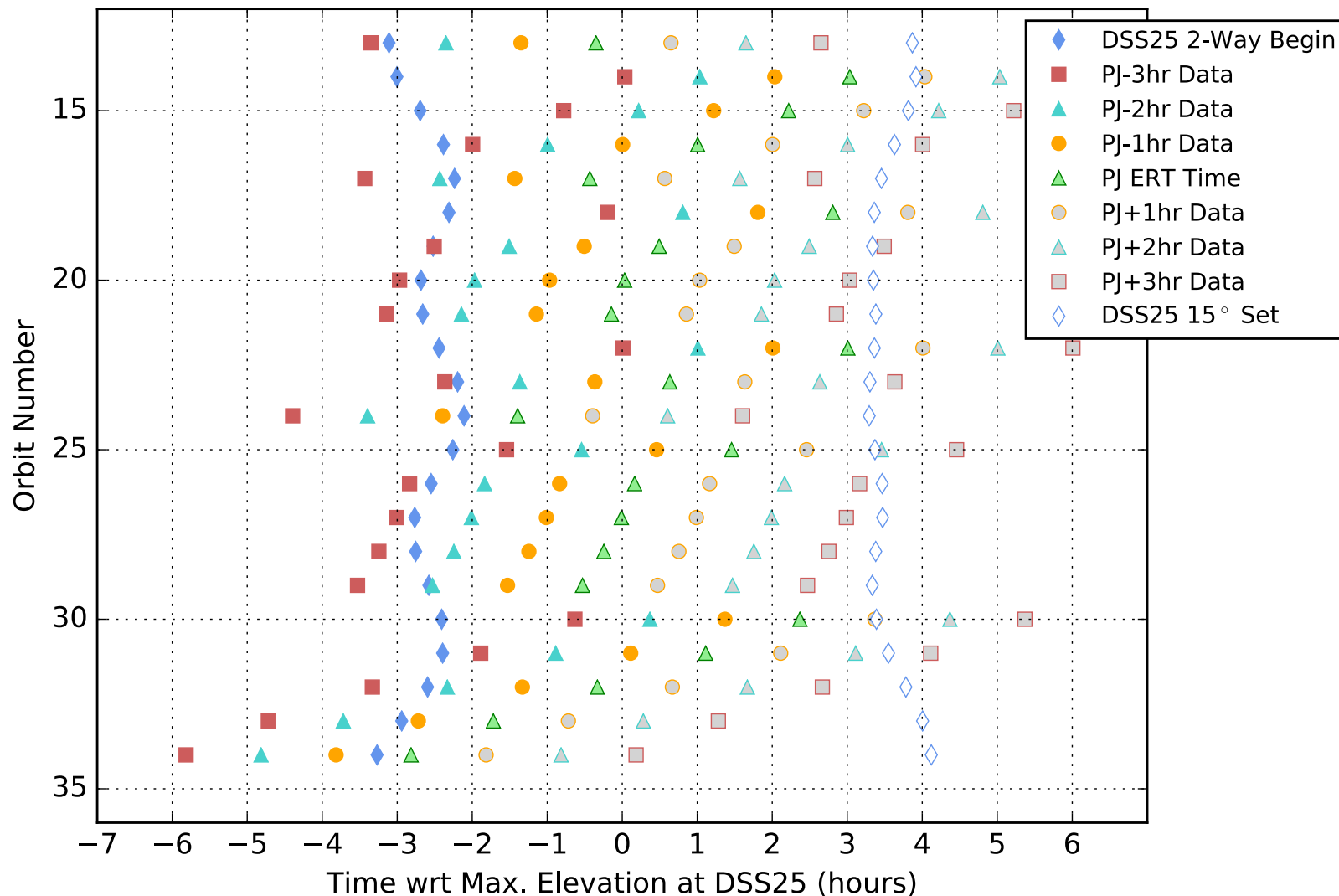
# Nav 180509 reference trajectory [3/6] Equator crossing longitude grid



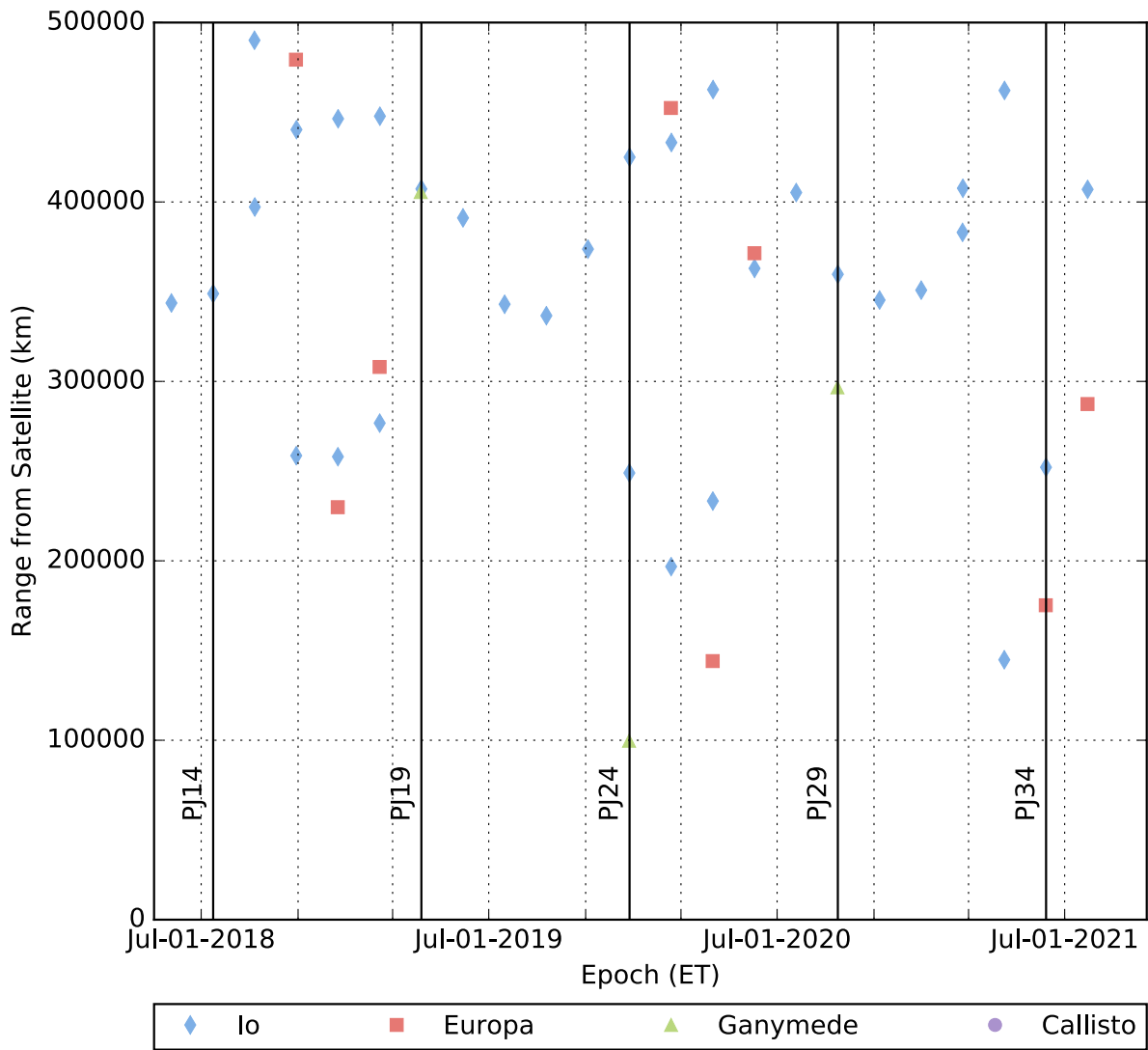
# Nav 180509 reference trajectory [4/6] Great Red Spot (GRS) longitude grid



# Nav 180509 reference trajectory [5/6] Goldstone coverage near perijoves



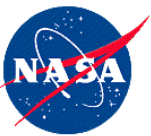
# Nav 180509 reference trajectory [6/6] Galilean satellite minimum ranges





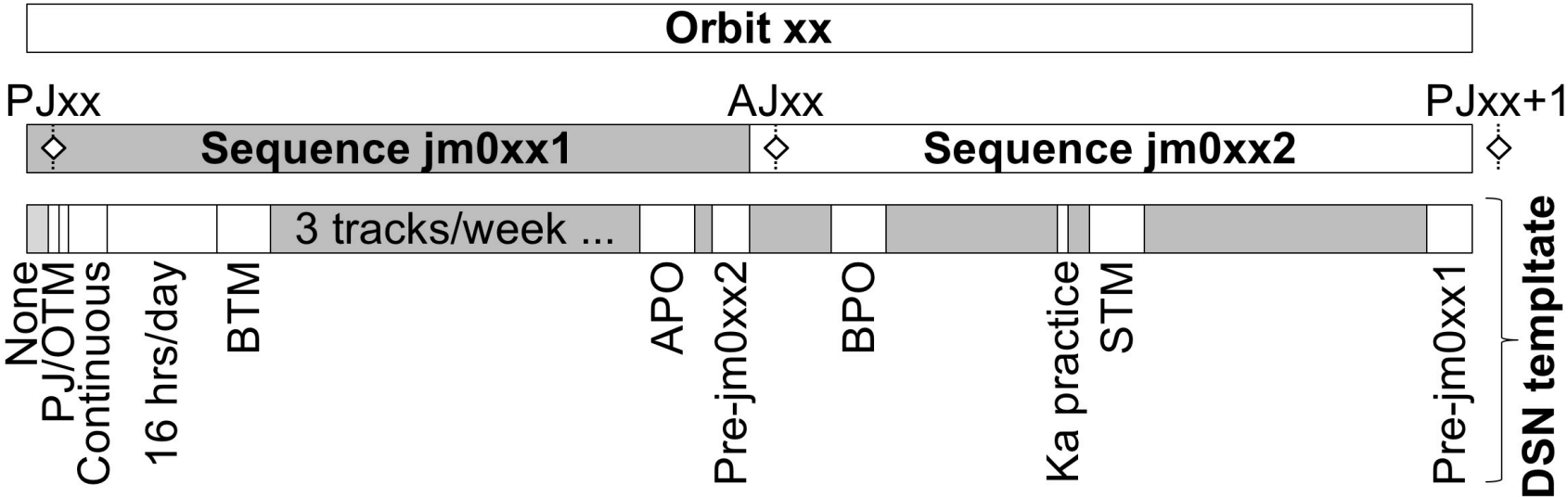
# Terminology – Numbering for perijoves, apojooves, orbits, and sequences [1/2]

- All **perijoves** (minimum range to Jupiter center) are numbered as follows:
  - PJ0 = when Jupiter Orbit Insertion (JOI) put us into orbit on 7/4/16 (Pacific Time)
  - PJ1 = 1st science perijove (8/27/16)
  - PJ2 = initially planned for Period Reduction Maneuver (PRM) on 10/19/16, but PRM was canceled, then we had safe mode soon before which precluded most science at PJ2
  - PJ3 = 2nd science perijove (12/11/16), PJ16 = 15th science perijove (10/29/18) ... etc.
- Each **apojoove** (AJ, maximum range to Jupiter) is numbered according to the previous PJ:
  - AJ0 was ~26.5 days after PJ0, AJ16 will be ~26.5 days after PJ16 ... etc.
- Each “**orbit**” informally refers to the period from ~PJ-1d to the next ~PJ-1d:
  - The idea is to include the main data collection and downlink periods around and after perijoves – this corresponds to how we define our sequences (see below)
  - Nav formally defines orbits as AJ to AJ, but we don’t usually use that for Juno
- We use 2 **sequences** (uplinked in advance for timed onboard commanding) during each 53-day orbit – in general, they are defined as follows (see next slide):
  - jm0xx1 = 1st sequence, from ~PJ-1d to ~AJ-1d (~26.5 days), including perijove data
  - jm0xx2 = 2nd sequence, from ~AJ-1d to ~PJ-1d (~26.5 days)
  - xx = sequence 16, etc. – and -1d is interpreted as -24h truncated to the previous hour
  - Note that prior to orbit 07, we used a different method with longer 1st sequences
  - Some future ~AJ-1d sequence boundaries may be moved due to holidays



# Terminology – Numbering for perijoves, apojoves, orbits, and sequences [2/2]

Relationship among **Orbit**, **Sequences**, and **DSN scheduling template**:



Orbits and sequences through PJ8 (different time scale):

Orbit	0	1	2	3	4	5	6	7	8...								
PJ/AJ	◇	◇	◇	◇	◇	◇	◇	◇	◇								
jm00...	*01	02	03	04	**05	06	31	32	41	42	51	52	61	62	71	72	81

(sequence) \*Preceded by JOI critical sequence \*\*Including pre-PJ2 safe mode

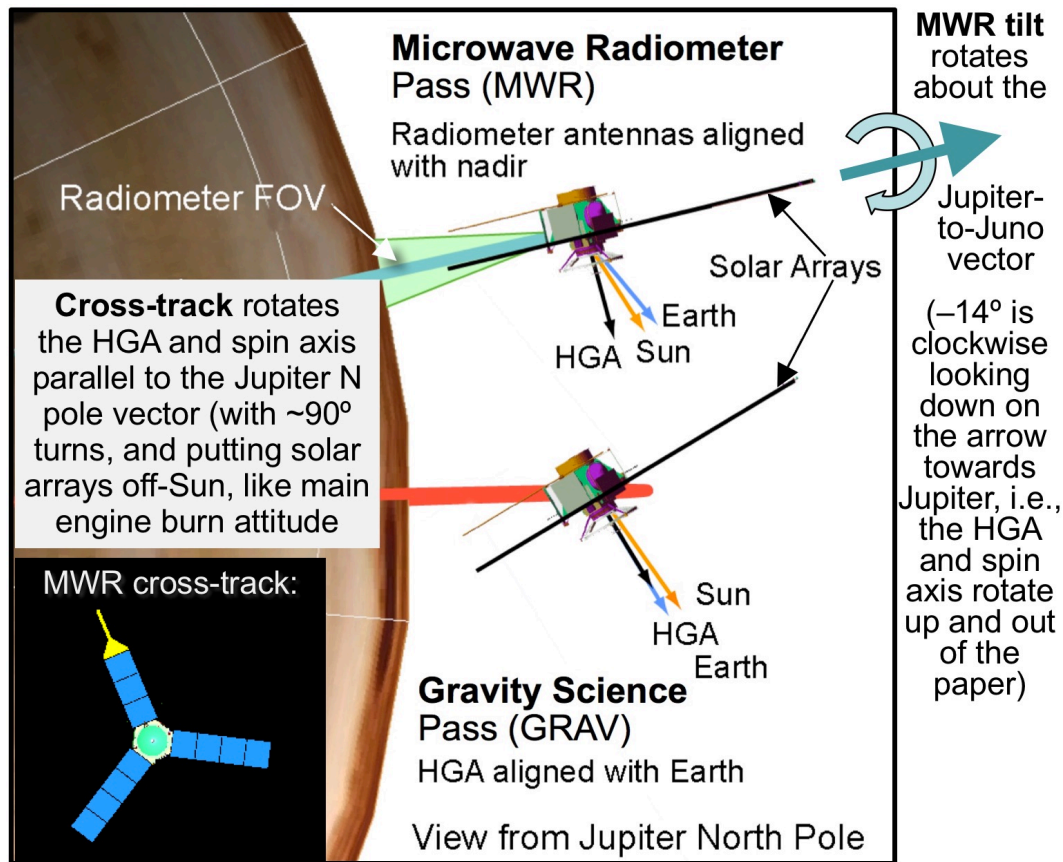


# Solar conjunctions (including near AJ16 and PJ24)

- Solar conjunctions occur every  $\sim 399$  days (Jupiter-Earth synodic period), which happens to be  $\sim 7.5 \times 53$ -day orbit period, so conjunctions repeat near perijoves and apojooves:
  - 09/26/2016 21:42,  $\sim \text{AJ1}+4\text{d}$  (slide 50 shows 5 conjunctions throughout orbital mission)
  - 10/26/2017 22:07,  $\sim \text{PJ9}+2\text{d}$
  - 11/26/2018 13:14,  $\sim \text{AJ16}+1\text{d}$  (upcoming – see plot with more times on slide 12)
  - 12/27/2019 18:56,  $\sim \text{PJ24}+1\text{d}$
  - 01/28/2021 19:25,  $\sim \text{AJ31}+2.5\text{d}$
- For conjunctions near apojoove (including **AJ16** and AJ31), we assume:
  - No science downlink for  $\text{SEP} < 3$  deg (easy, since no APO maneuvers in those orbits)
  - Duration of each  $\text{SEP} < 3$  deg period is  $\sim 7$ -8 days
- For conjunctions near perijove (PJ9 and **PJ24**), we assume:
  - No science downlink for  $\text{SEP} < 3$  deg
  - Request increased DSN coverage after  $\text{SEP} > 3$  deg

# Perijove attitude (old) explanations: GRAV, MWR, MWR tilt, and (proposed) MWR cross-track

- PJ attitudes (**GRAV**, **MWR**, **MWR tilt**, and (proposed) **MWR cross-track**) are shown:

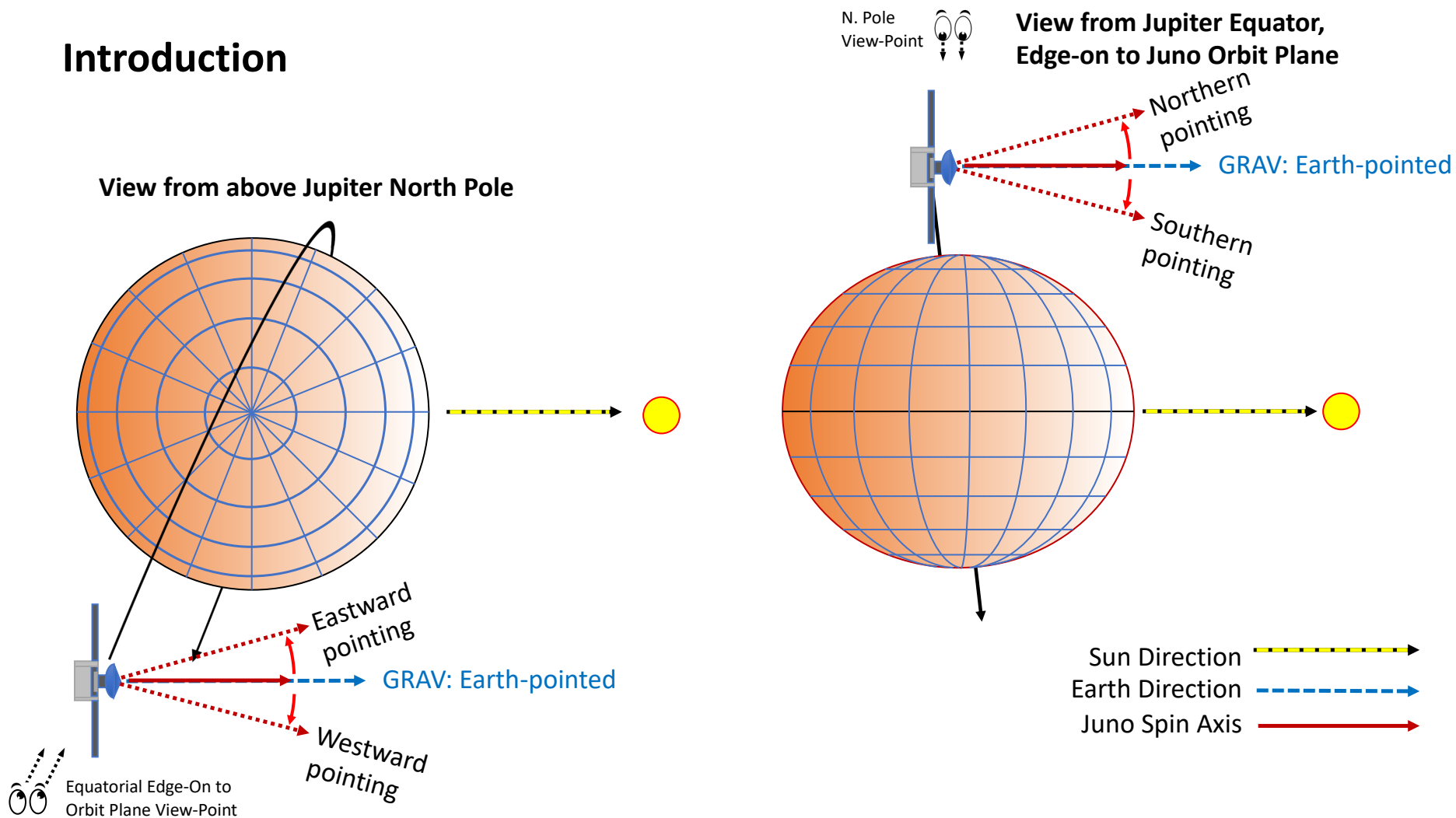


- Note that during MWR or MWR tilt attitudes near perijove, the Earth and Sun can actually be much further away from the spin axis (arrow for HGA direction) than shown here (in later orbits when the orbit enters the noon-midnight part of Jupiter's magnetosphere). This figure has not been updated for the longer mission.
- Similarly, during GRAV attitudes near perijove, the Jupiter nadir direction can actually be much further away from the spin plane than shown here (and in fact, Jupiter nadir will be nearly opposite the spin axis direction near PJ23 and PJ24).

- Proposed MWR cross-track (XTk) attitude would have spin axis pointed near Jupiter N or S pole.

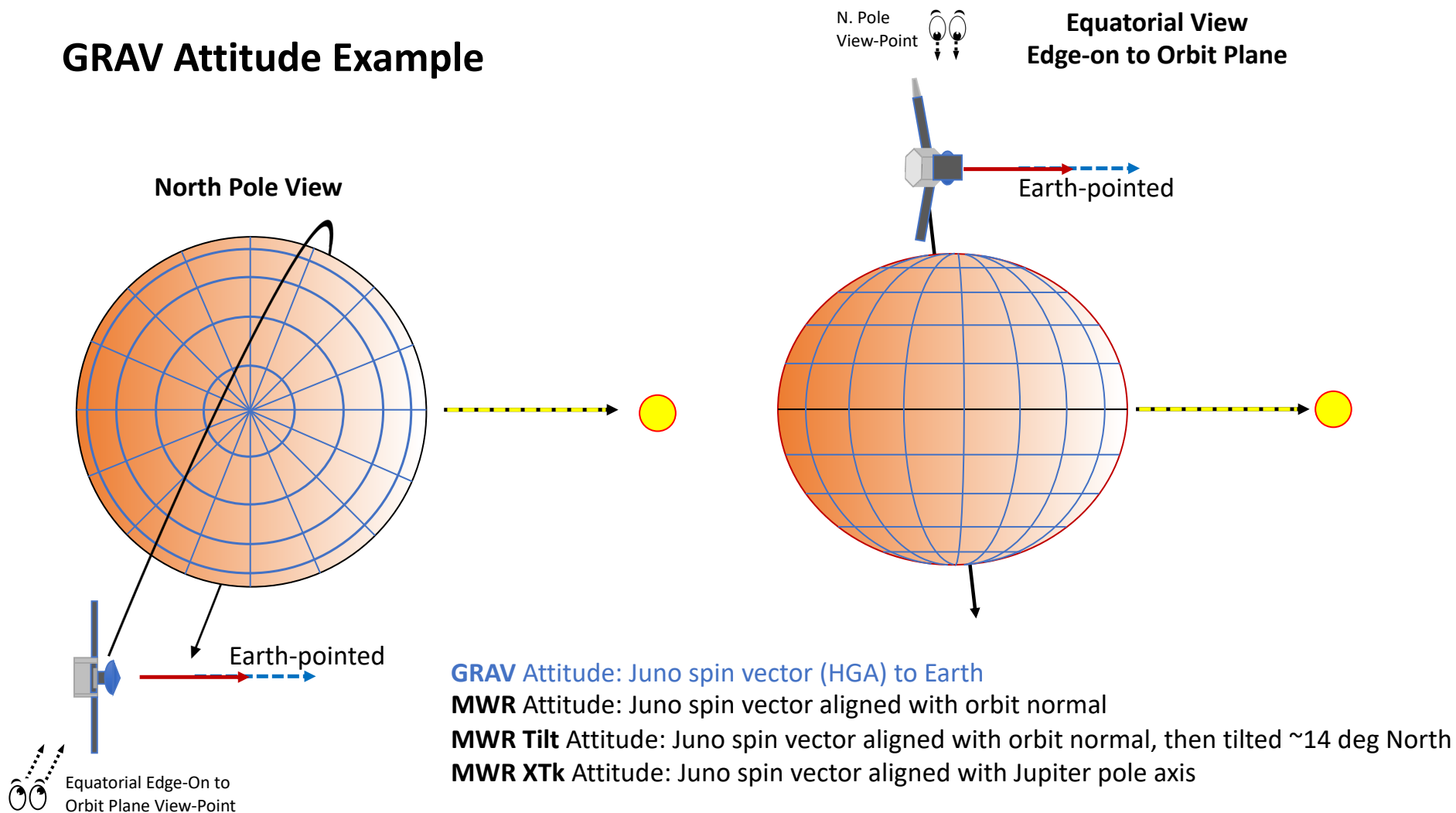
# Perijove attitudes – More explanations (from Marty Brennan) [1/8]

## Introduction



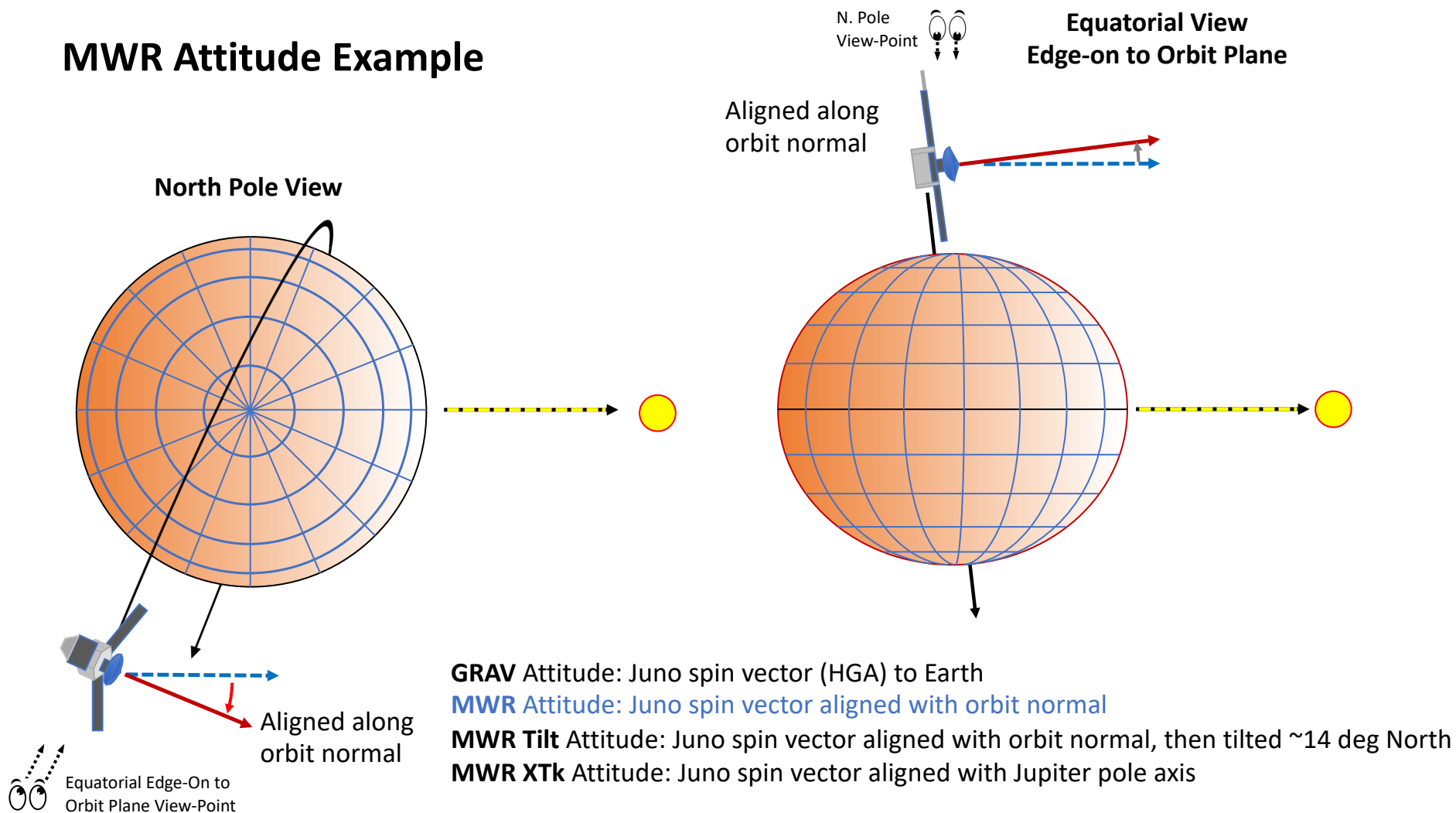
# Perijove attitudes – More explanations (from Marty Brennan) [2/8]

## GRAV Attitude Example



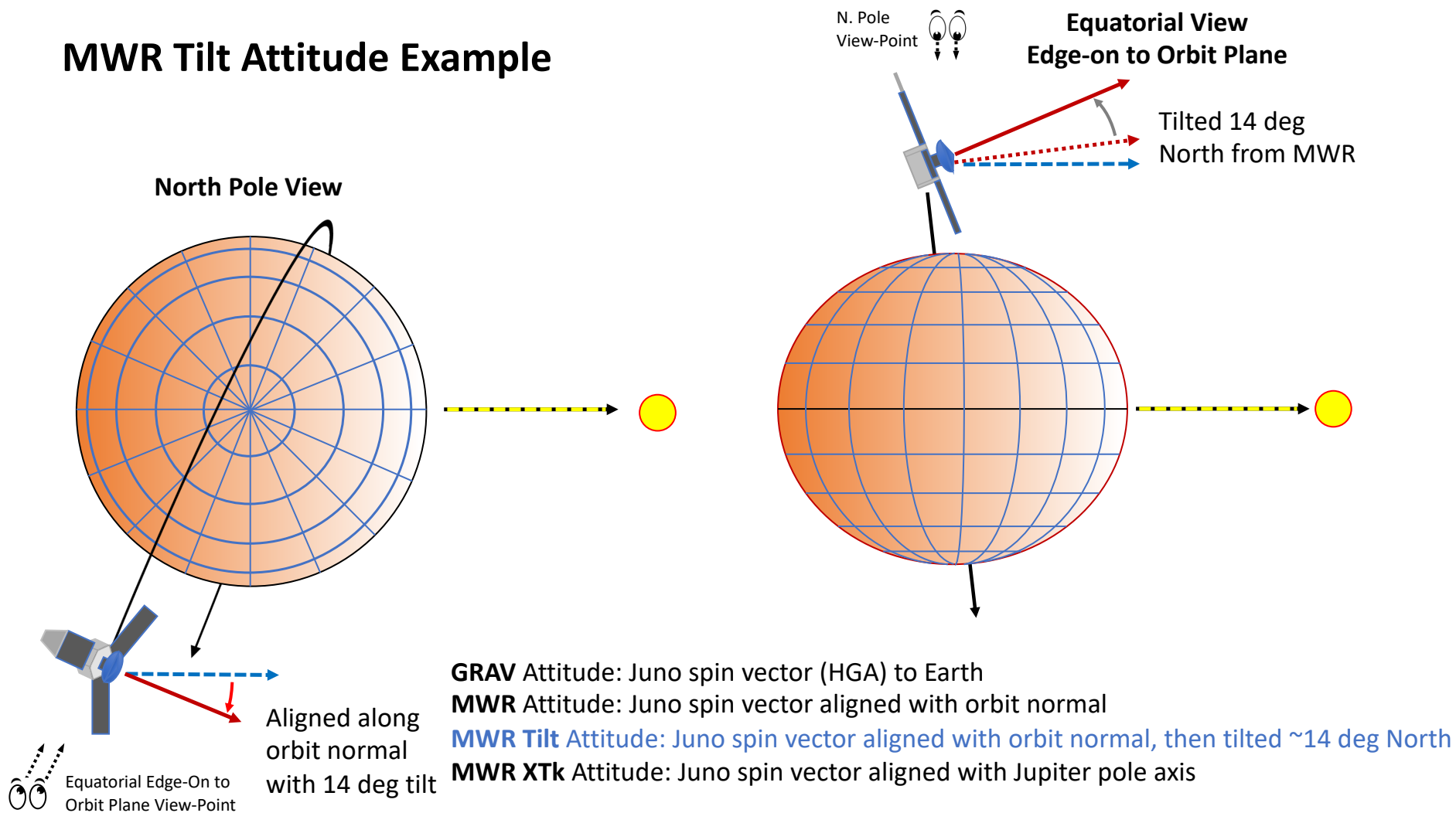
# Perijove attitudes – More explanations (from Marty Brennan) [3/8]

## MWR Attitude Example



# Perijove attitudes – More explanations (from Marty Brennan) [4/8]

## MWR Tilt Attitude Example

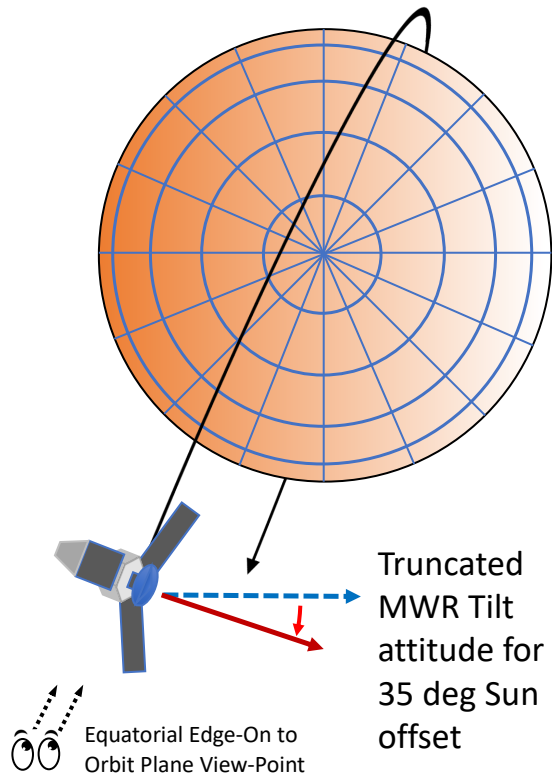


# Perijove attitudes – More explanations (from Marty Brennan) [5/8]

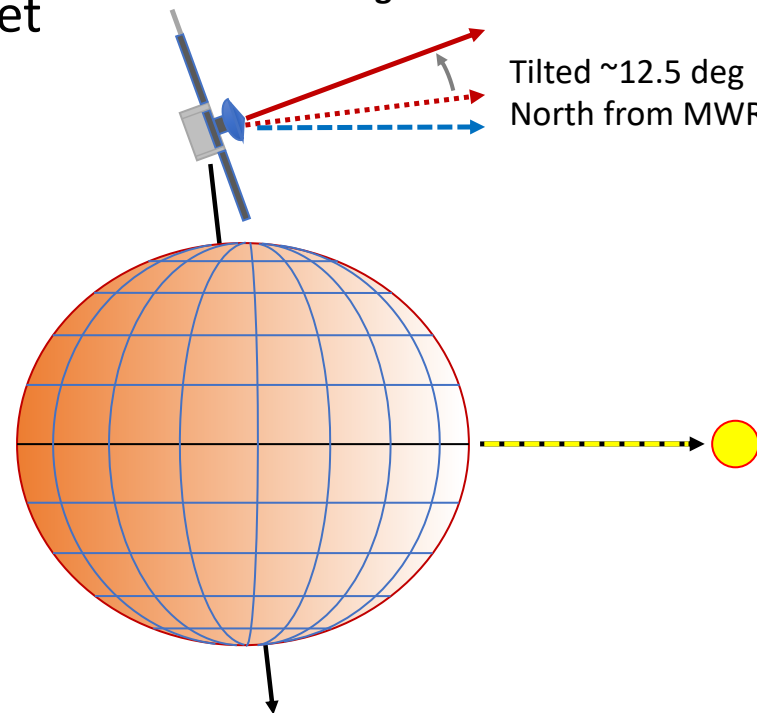
## 35 deg Sun Offset Attitude Example

PJ09 MWR Tilt truncated to 35° Sun offset  
(untruncated Sun offset = 39.4°)

North Pole View



N. Pole View-Point  
Equatorial View  
Edge-on to Orbit Plane  
Tilted ~12.5 deg North from MWR



**GRAV** Attitude: Juno spin vector (HGA) to Earth

**MWR** Attitude: Juno spin vector aligned with orbit normal

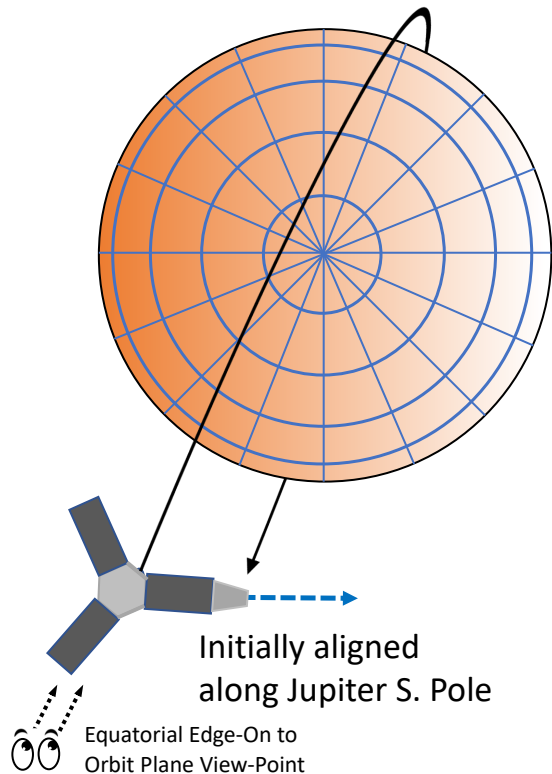
**MWR Tilt** Attitude: Juno spin vector aligned with orbit normal, then tilted ~14 deg North

**MWR Xtk** Attitude: Juno spin vector aligned with Jupiter pole axis

# Perijove attitudes – More explanations (from Marty Brennan) [6/8]

## Proposed MWR Cross-track Attitude Example

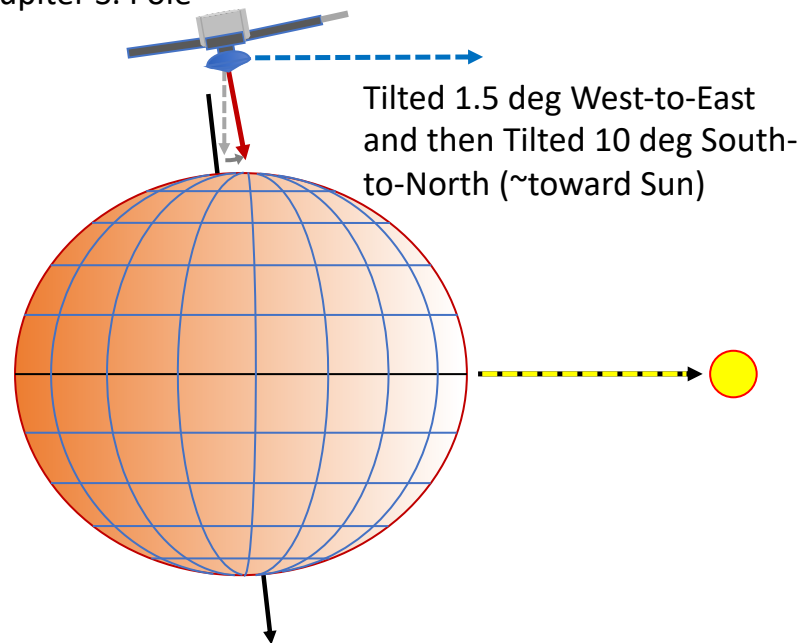
North Pole View



N. Pole  
View-Point

Initially aligned  
along Jupiter S. Pole

Equatorial View  
Edge-on to Orbit Plane



**GRAV** Attitude: Juno spin vector (HGA) to Earth

**MWR** Attitude: Juno spin vector aligned with orbit normal

**MWR Tilt** Attitude: Juno spin vector aligned with orbit normal, then tilted ~14 deg North

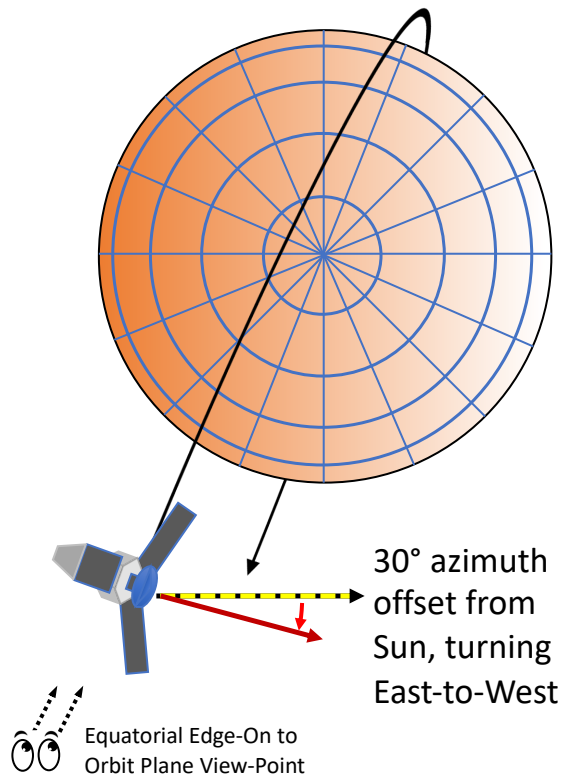
**MWR XTk** Attitude: Juno spin vector aligned with Jupiter pole axis

# Perijove attitudes – More explanations (from Marty Brennan) [7/8]

## -30/+20 Offset Attitude Example

Truncated to 35° Offset from Sun

North Pole View



**GRAV** Attitude: Juno spin vector (HGA) to Earth

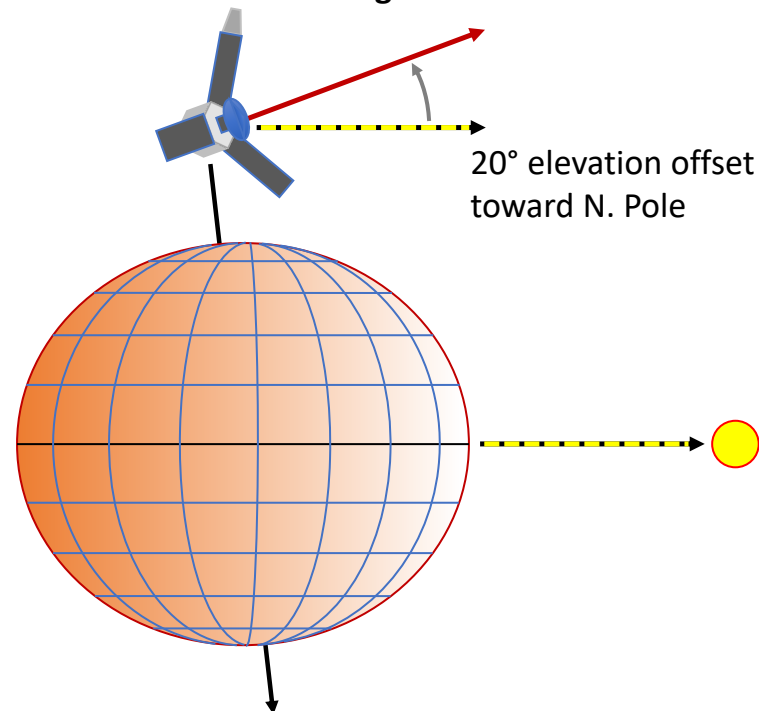
**MWR** Attitude: Juno spin vector aligned with orbit normal

**MWR Tilt** Attitude: Juno spin vector aligned with orbit normal, then tilted ~14 deg North

**MWR XTk** Attitude: Juno spin vector aligned with Jupiter pole axis

N. Pole View-Point

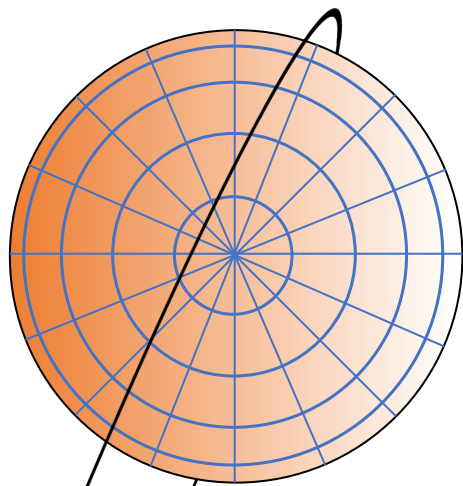
Equatorial View  
Edge-on to Orbit Plane



# Perijove attitudes – More explanations (from Marty Brennan) [8/8]

## -30/+5 Offset Attitude Example (no truncation required)

North Pole View

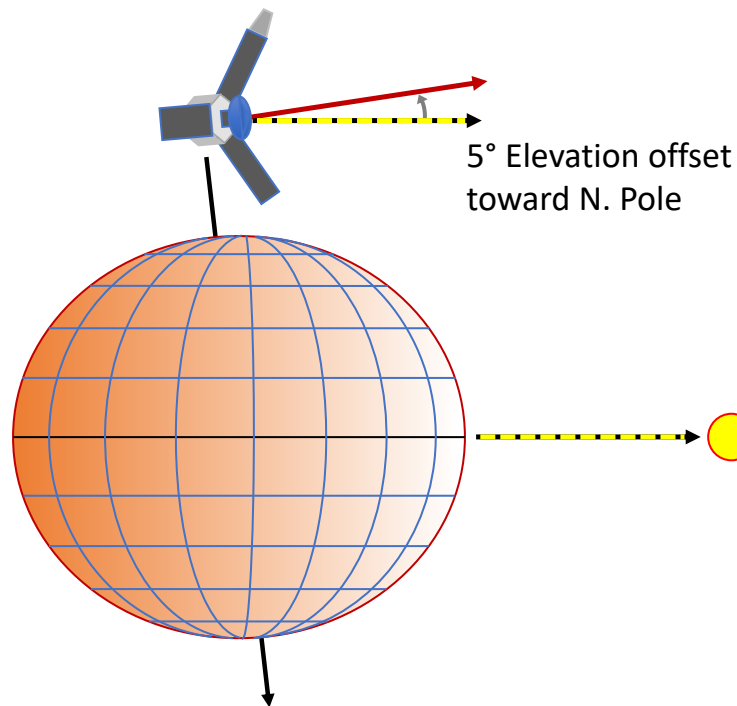


30° azimuth  
offset from  
Sun, turning  
East-to-West

Equatorial Edge-On to  
Orbit Plane View-Point

N. Pole  
View-Point

Equatorial View  
Edge-on to Orbit Plane



5° Elevation offset  
toward N. Pole

**GRAV** Attitude: Juno spin vector (HGA) to Earth

**MWR** Attitude: Juno spin vector aligned with orbit normal

**MWR Tilt** Attitude: Juno spin vector aligned with orbit normal, then tilted ~14 deg North

**MWR XTk** Attitude: Juno spin vector aligned with Jupiter pole axis



# Additional attitude (SPICE C-kernel) information (and relation to perijove attitudes)

- C-kernel (CK) – a reference attitude profile useful for science planning – was generated by Marty Brennan for the 180509 reference trajectory using these assumed perijove attitudes:
  - \*2 **MWR** (nadir) for PJ4, and PJ7 (\*reference CK starts > PJ12, so use ops CKs earlier)
  - \*2 **MWR tilted 14 deg** for PJ5, and PJ9 (the latter limited to **35 deg off-Sun**)
  - 2 **MWG -30/+20** (azimuth & elevation) for PJ12 and PJ16 (limited to **35 deg off-Sun**)
  - 1 **MWG -30/+5** (azimuth & elevation) for PJ20
  - 1 **MWR cross-track** proposed for PJ19 – spin axis parallel to Jupiter N pole (although current proposal has spin axis to S pole tilted 1.5 deg E and 10 deg N – see CK below)
  - And **GRAV** (Earth-pointed for Gravity Science) for the other perijoves, including PJ35 (if a deorbit burn is done near AJ34, it'll use GRAV attitude at PJ35 for downlink)
  - See previous slides (including Marty Brennan's) for more attitude explanations
  - Otherwise, a constant Earth-pointed attitude is assumed outside of the PJ period
- C-kernels (plus comment/description files and sanity-check plots) are available at:
  - Baseline CK: <https://naif.jpl.nasa.gov/pub/naif/JUNO/misc/nomck180710/>
  - PJ19 S-pointing CK: <https://naif.jpl.nasa.gov/pub/naif/JUNO/misc/nomck180827/>
- PJ period is modeled from PJ-19h45m until first thruster firing for Orbit Trim Maneuver at PJ+6h03m (GRAV) or PJ+6h21m (MWR types), with a few exceptions:
  - There is no OTM after PJ9 or PJ24 (due to solar conjunctions) or PJ34 (due to deorbit), so the PJ period ends at PJ+6h for those cases before constant Earth-pointing resumes
  - Proposed MWR cross-track PJ is modeled from PJ-1h to PJ+1h, due to off-Sun attitude
- Deorbit burn near AJ34 is modeled as vector-mode (instead of turn-burn-turn, due to a smaller burn required to deorbit from 53-day trajectory), so it stays Earth-pointed



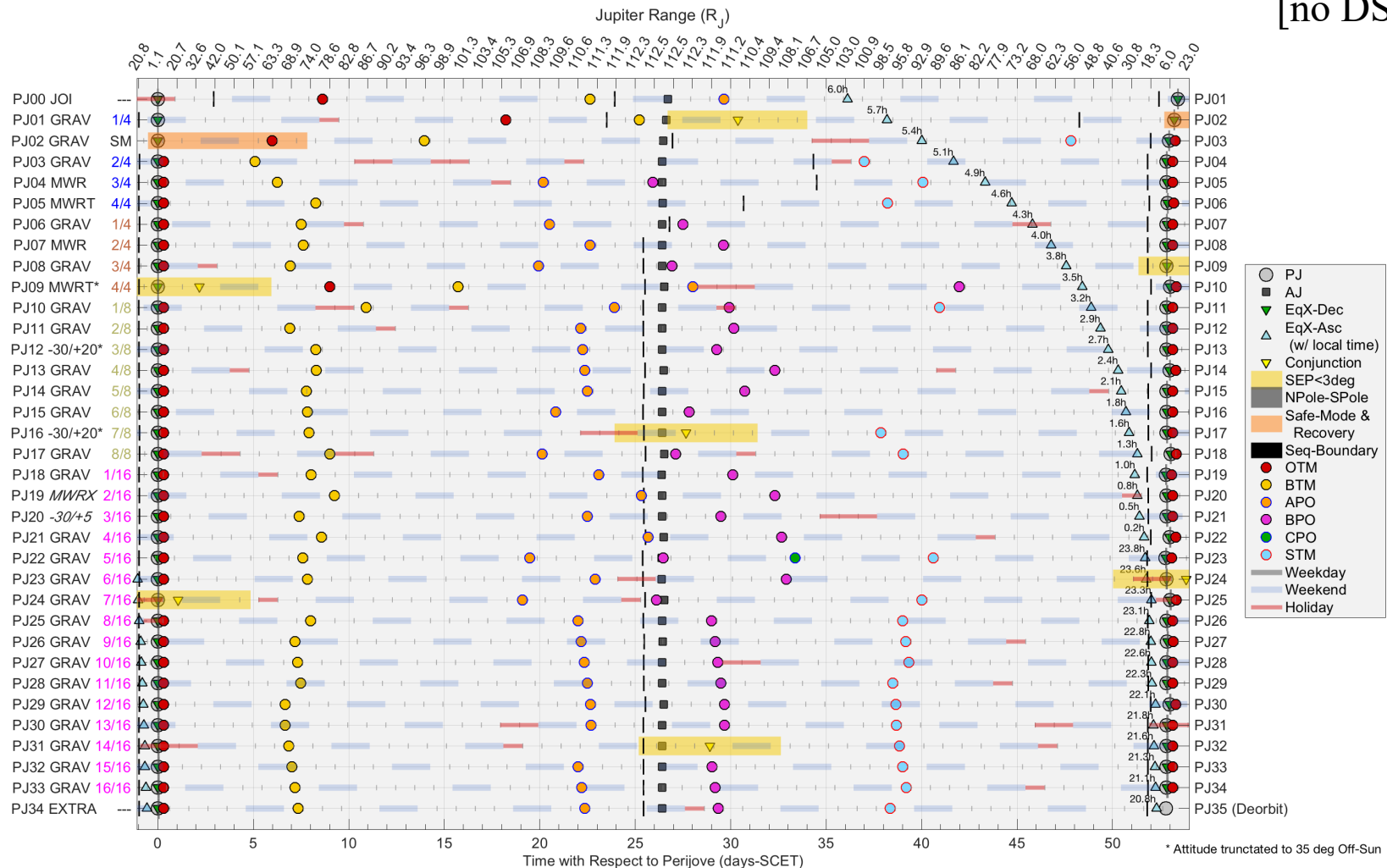
# Stacked linear timelines [1/13] (geometry and other info for each orbit or PJ)

- Marty Brennan's **stacked linear timelines** (with orbits or PJs orbits stacked vertically, and geometry and other information plotted on each orbit or PJ row) (next 12 slides):
  - Full 53d orbits (**6 slides**), including geometric milestones (PJ, AJ, EqX-Ascending), SEP < 3 deg periods, solar conjunctions, maneuvers, sequence boundaries, weekdays plus weekends and holidays, and Jupiter range in R<sub>j</sub> on horizontal axis
  - PJ ± 1d periods (**6 slides**), including geometric milestones (EqX-Ascending, PJ, EqX-Descending, NPole-SPole intervals), OTM, SEP < 3 deg periods, sequence boundary, weekdays plus weekends and holidays, PJ attitude intervals, and Jupiter range in R<sub>j</sub> on horizontal axis
  - Baseline PJ attitude is listed to the left of each plot, and local time at inbound equator crossings (EqX-Asc) is labeled in hours on full 53d plot
  - **Each set of 6 slides progressively adds DSN info** (items can be toggled on or off):
    - No DSN
    - View periods only (very thin lines below information for each orbit)
    - With ops SAFs (Station Allocation Files), showing actual tracks through orbit 16
      - With prime and 2nd shifts (roughly 8 am to 5 pm and 4 pm to 1 am in Denver)
    - With SAFs based on DSN template (orbits 4 through 34) in place of ops SAFs
      - With prime and 2nd shifts
- For latest reference trajectory, attitudes, maneuvers, and conjunction timing

# Stacked linear timelines [2/13] (geometry and other info for each orbit or PJ)

- Marty Brennan's **stacked linear timelines** – Full 53d orbits

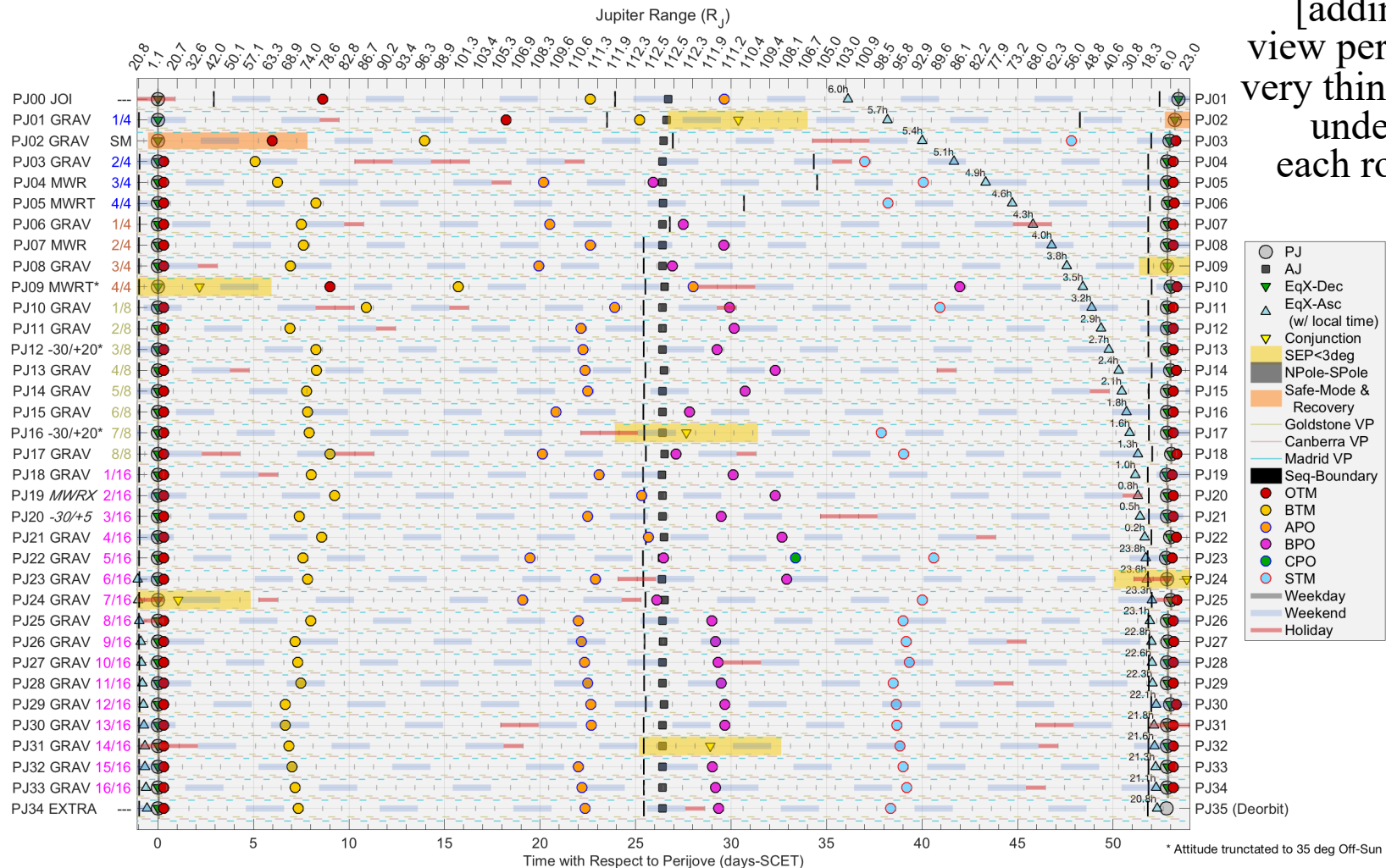
[no DSN]





# Stacked linear timelines [3/13] (geometry and other info for each orbit or PJ)

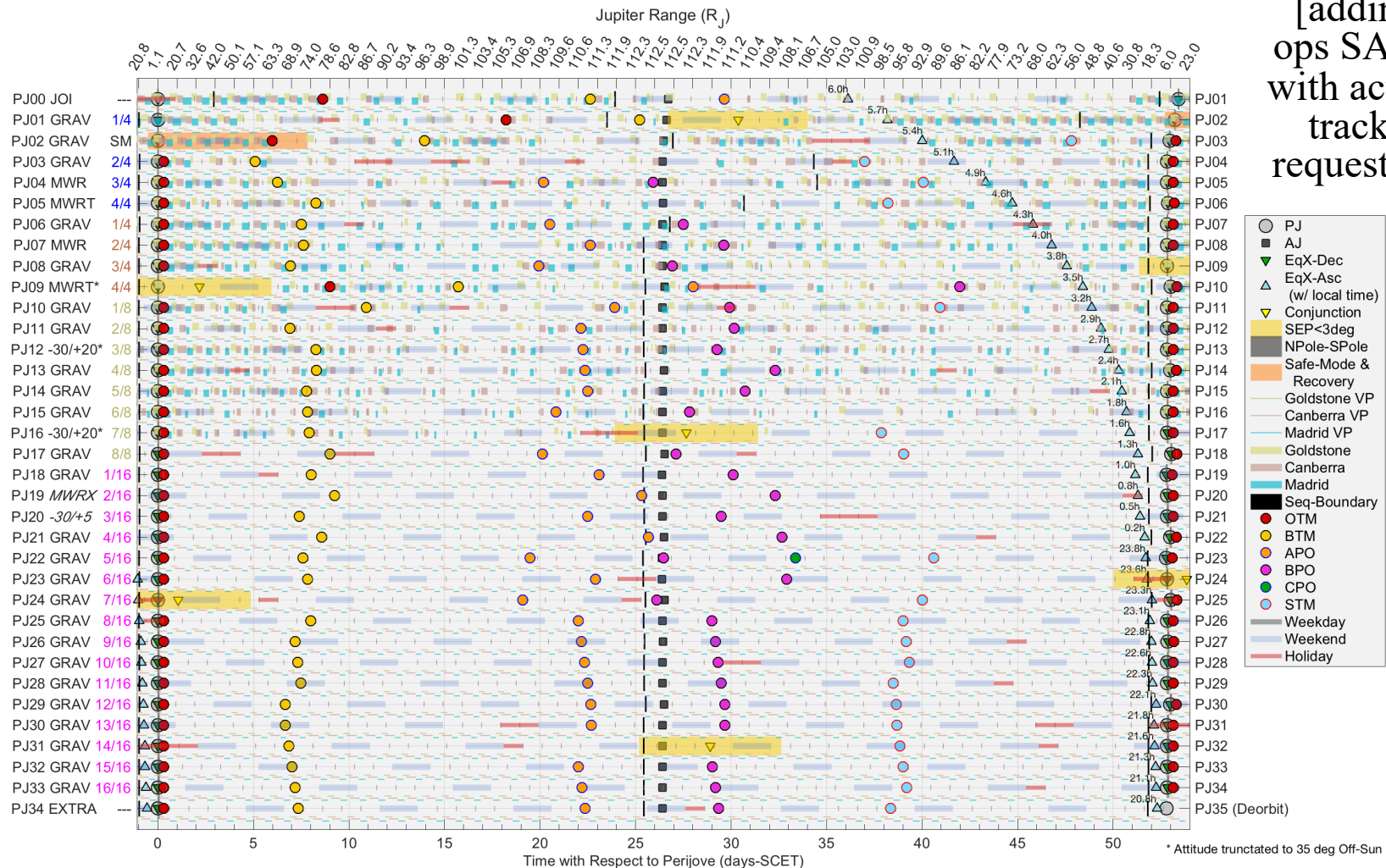
- Marty Brennan's **stacked linear timelines** – Full 53d orbits





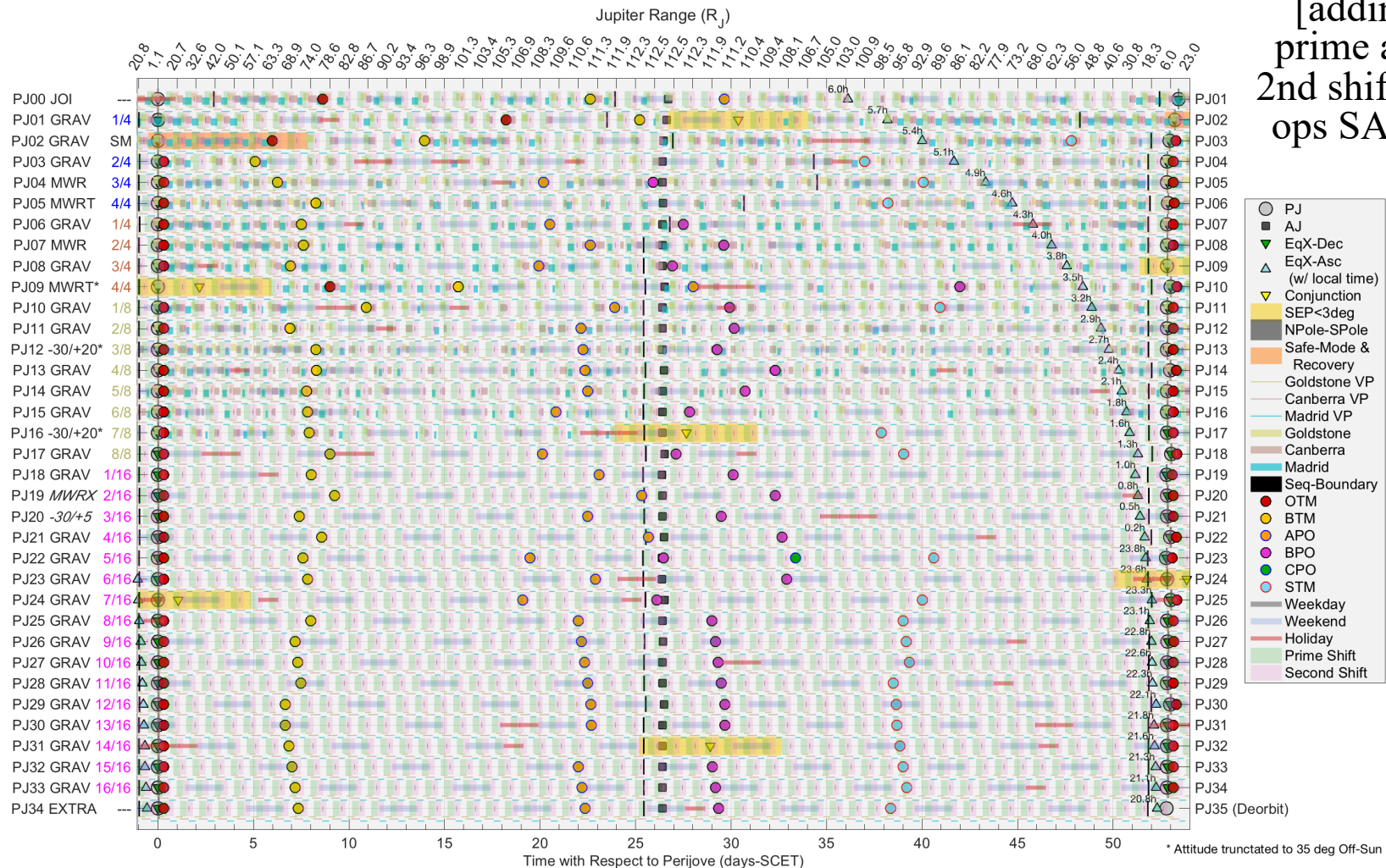
# Stacked linear timelines [4/13] (geometry and other info for each orbit or PJ)

- Marty Brennan's **stacked linear timelines** – Full 53d orbits



# Stacked linear timelines [5/13] (geometry and other info for each orbit or PJ)

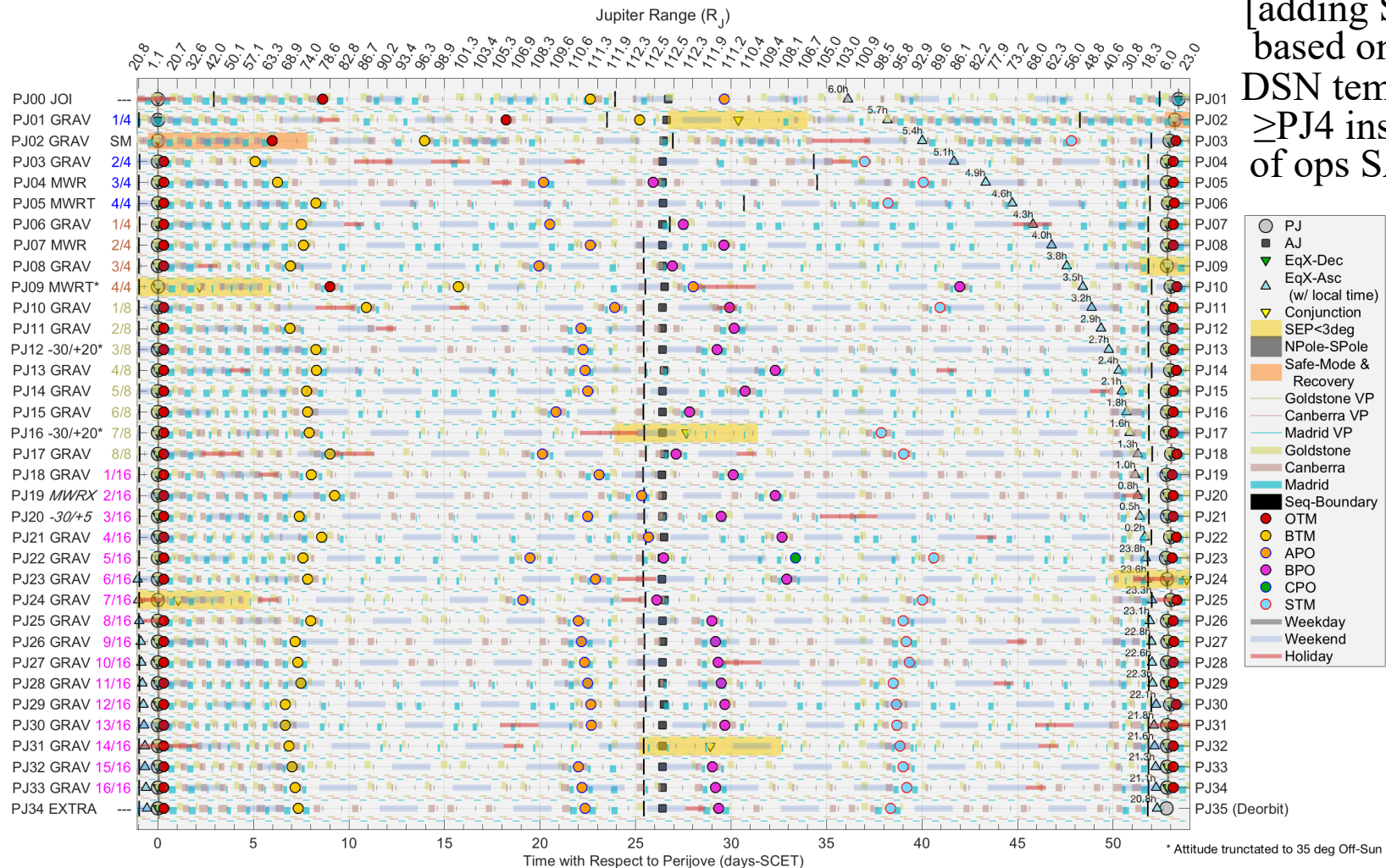
- Marty Brennan's **stacked linear timelines** – Full 53d orbits



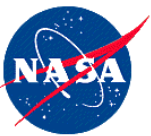


# Stacked linear timelines [6/13] (geometry and other info for each orbit or PJ)

- Marty Brennan's **stacked linear timelines** – Full 53d orbits

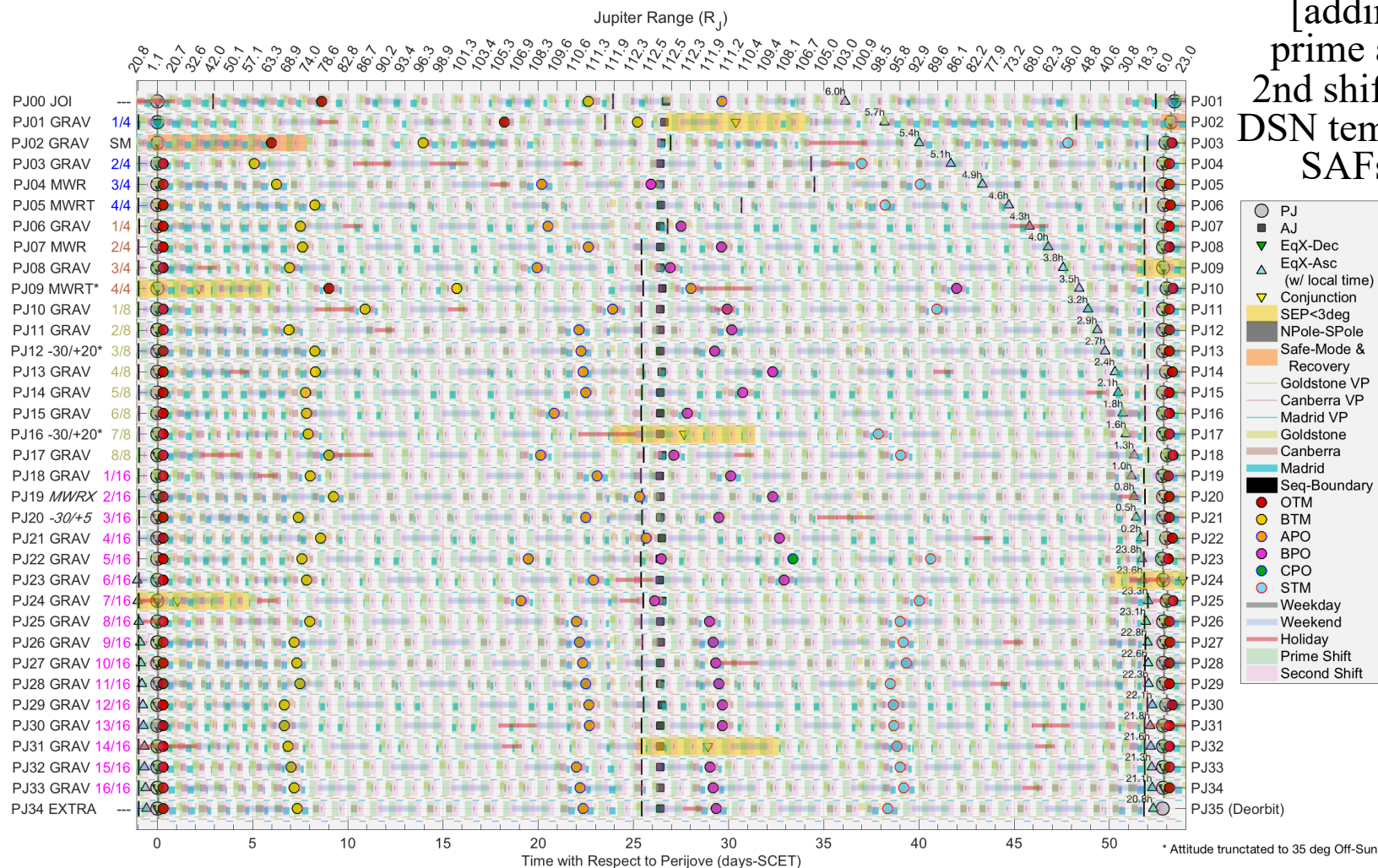


[adding SAFs  
based on our  
DSN template  
≥PJ4 instead  
of ops SAFs]



# Stacked linear timelines [7/13] (geometry and other info for each orbit or PJ)

- Marty Brennan's **stacked linear timelines** – Full 53d orbits

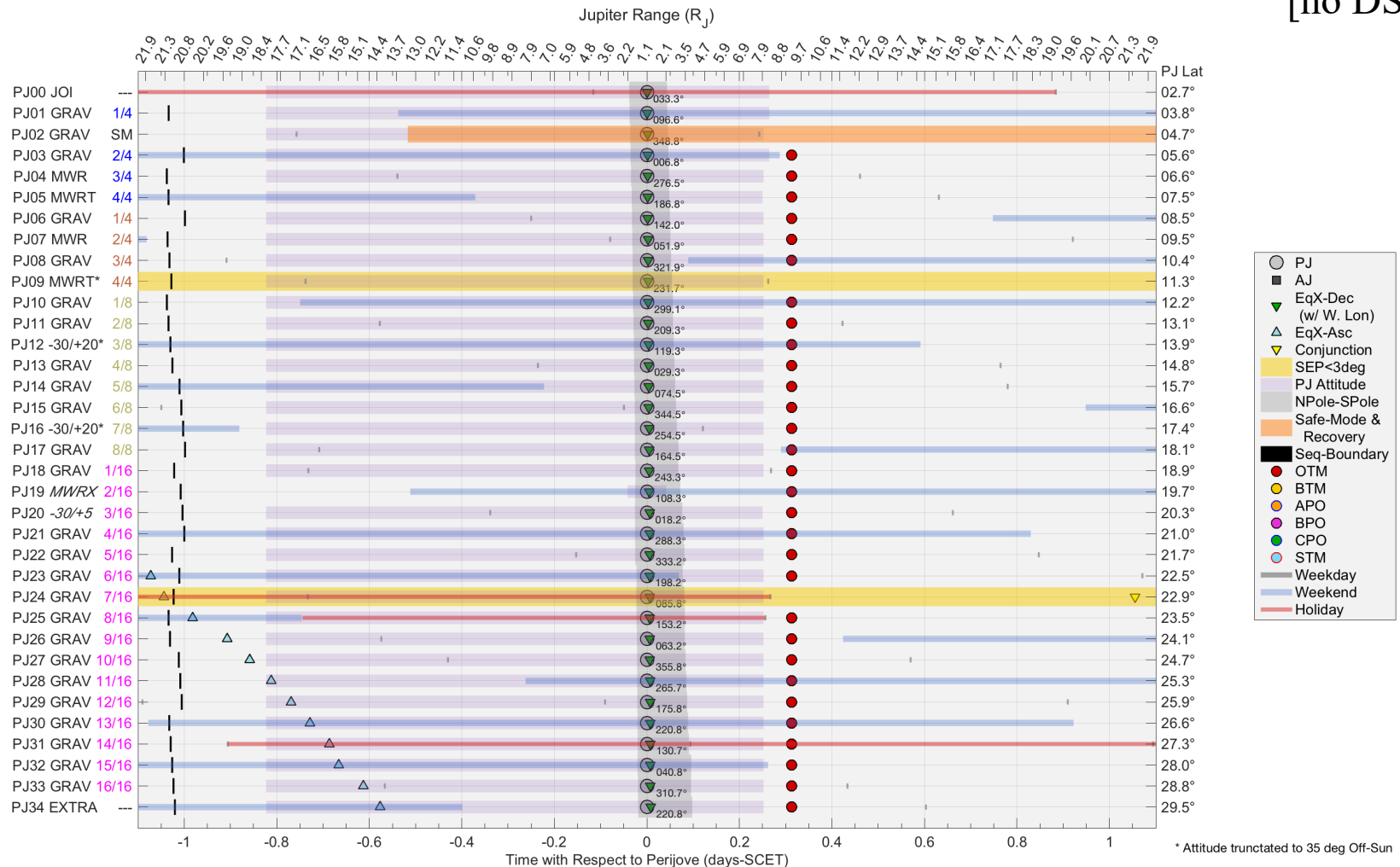




# Stacked linear timelines [8/13] (geometry and other info for each orbit or PJ)

- Marty Brennan's **stacked linear timelines** – PJ $\pm$ 1d periods

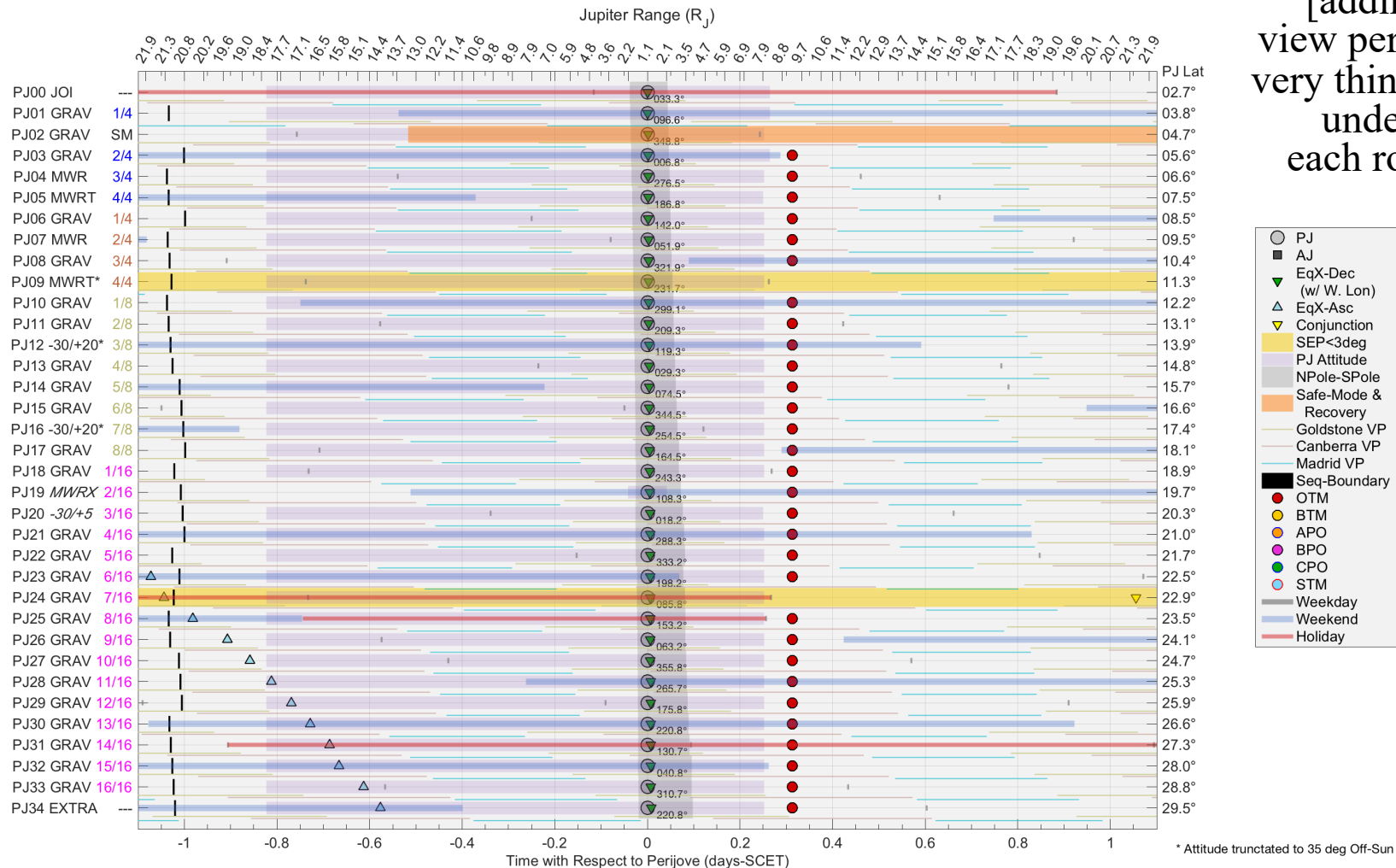
[no DSN]

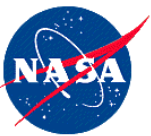




# Stacked linear timelines [9/13] (geometry and other info for each orbit or PJ)

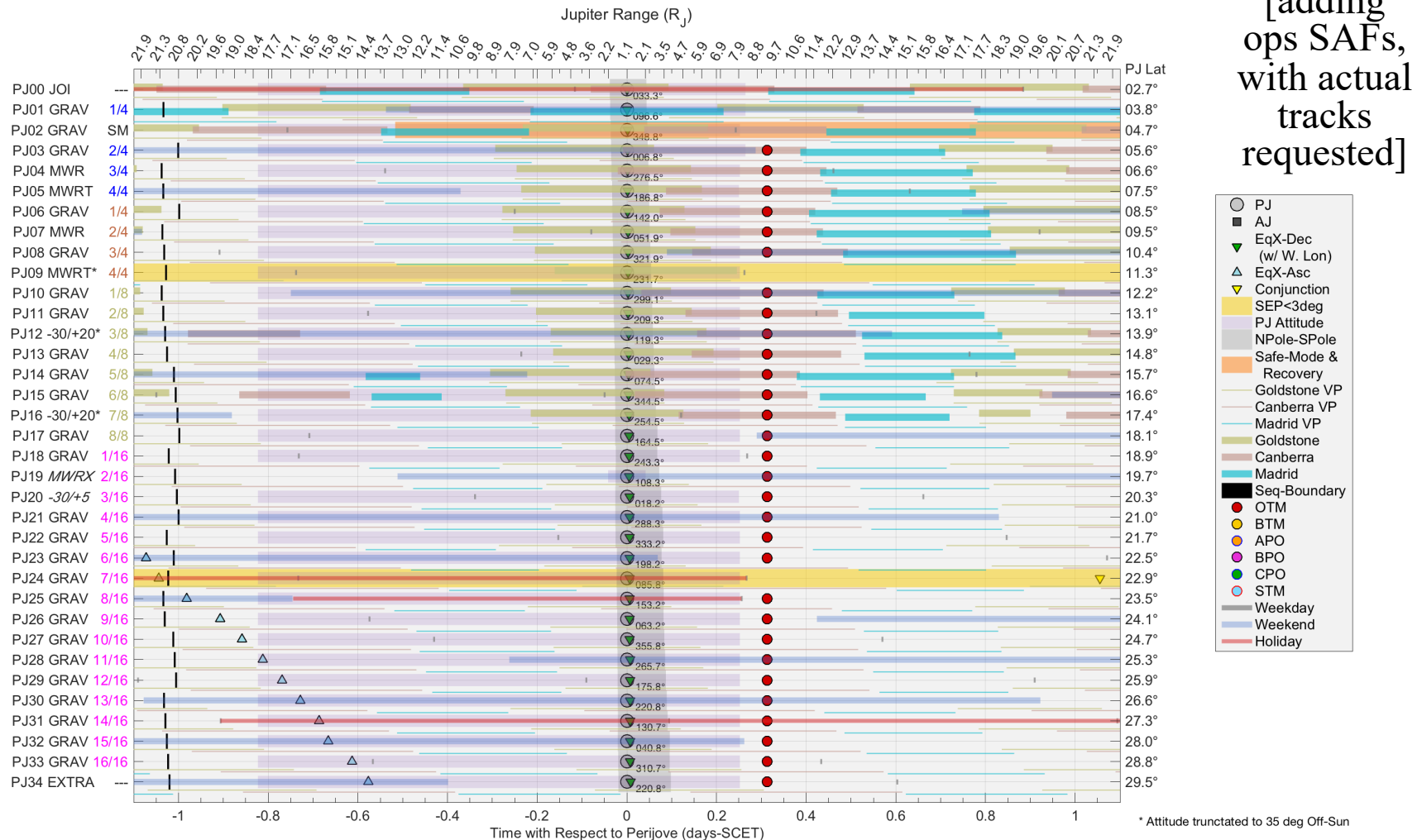
- Marty Brennan's **stacked linear timelines** – PJ $\pm$ 1d periods





# Stacked linear timelines [10/13] (geometry and other info for each orbit or PJ)

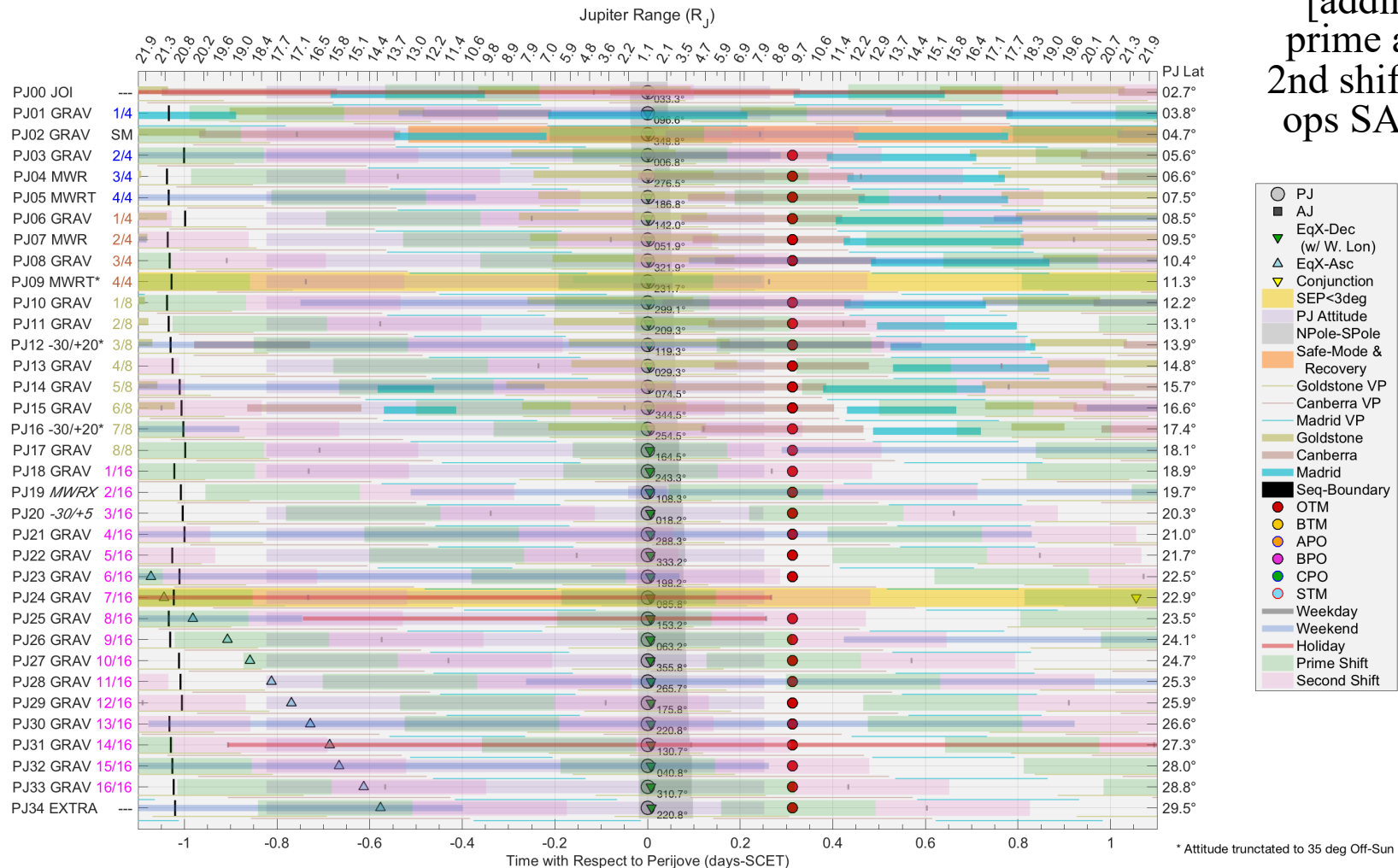
- Marty Brennan's **stacked linear timelines** – PJ $\pm$ 1d periods

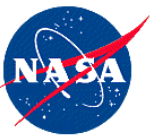




# Stacked linear timelines [11/13] (geometry and other info for each orbit or PJ)

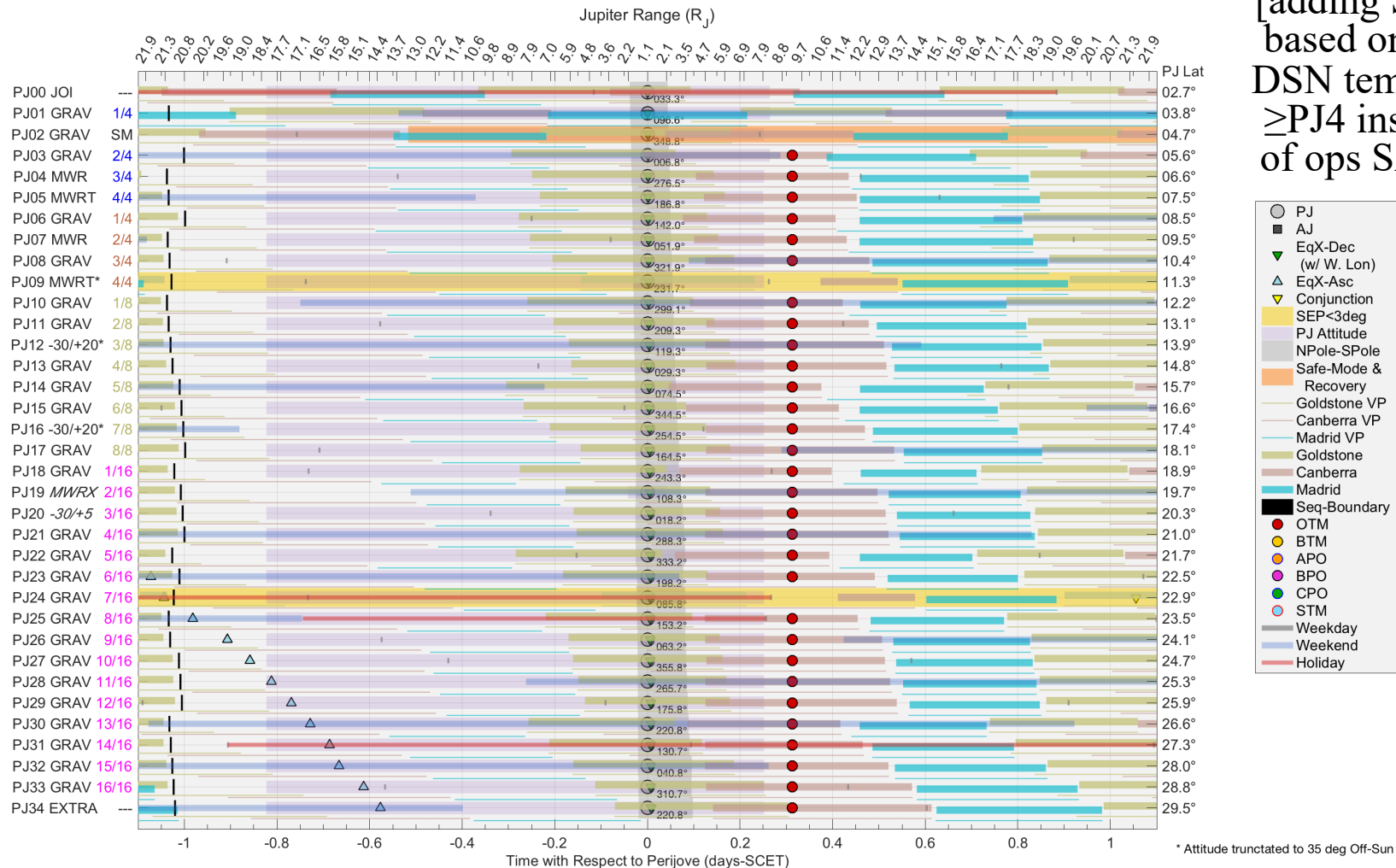
- Marty Brennan's **stacked linear timelines** – PJ $\pm$ 1d periods

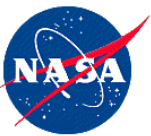




# Stacked linear timelines [12/13] (geometry and other info for each orbit or PJ)

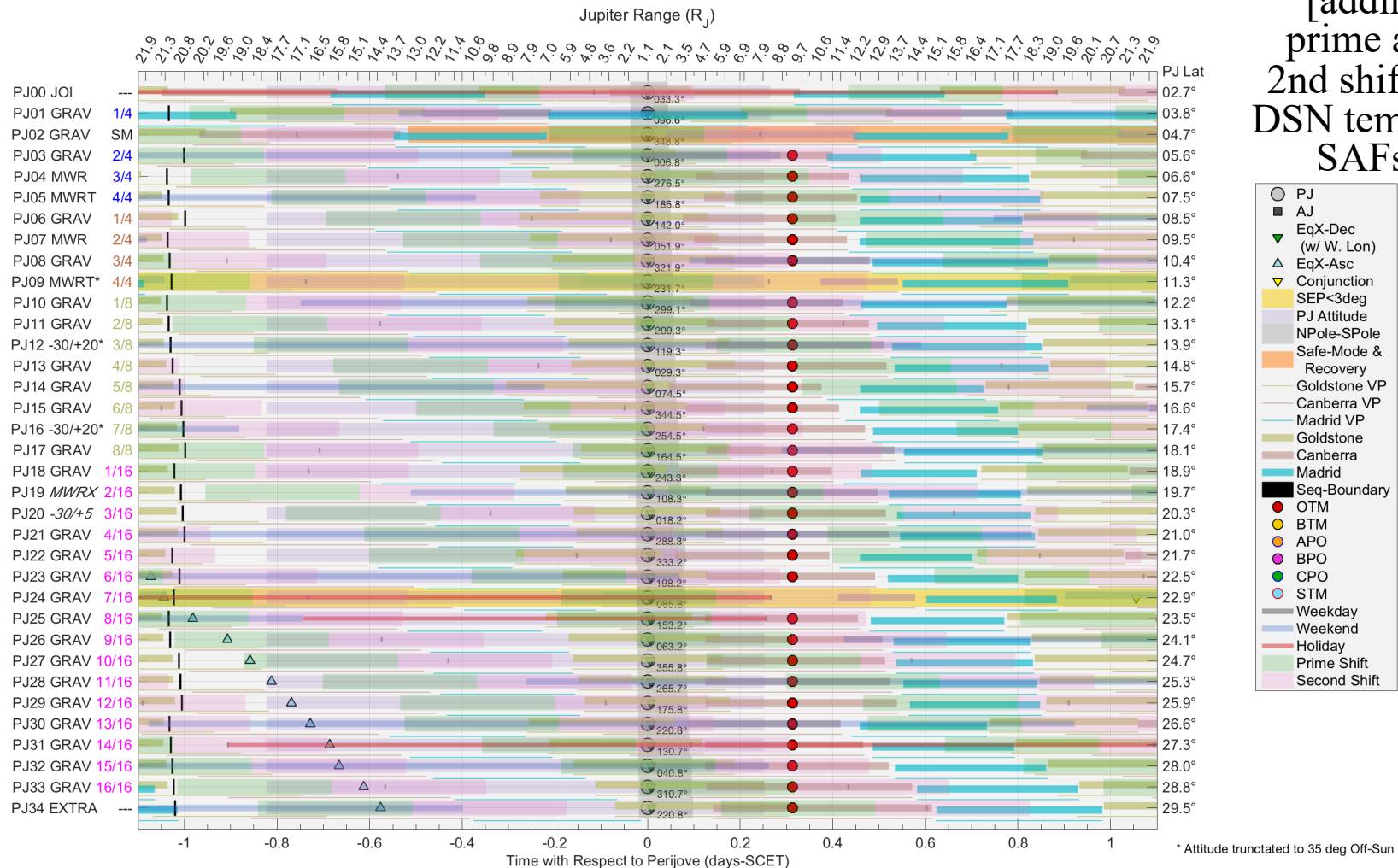
- Marty Brennan's **stacked linear timelines** – PJ $\pm$ 1d periods





# Stacked linear timelines [13/13] (geometry and other info for each orbit or PJ)

- Marty Brennan's **stacked linear timelines** – PJ $\pm$ 1d periods

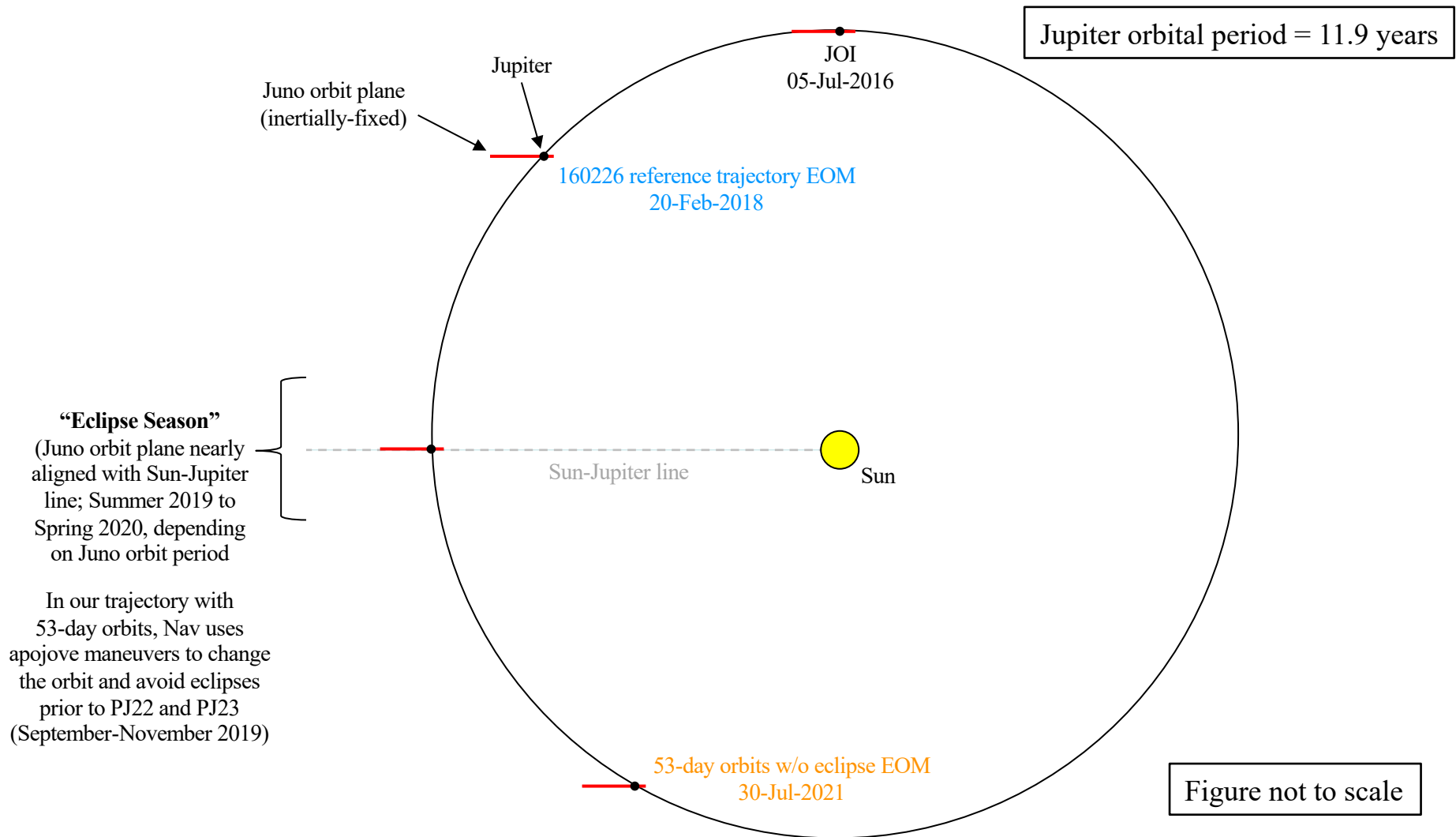




# Maneuver strategy

- OTM = Orbit Trim Maneuver
  - Required for all orbits to target longitude/timing of next perijove
  - As a rule, these start at PJ+7.5h (to avoid perijove data collection)
  - Exceptions due to solar conjunction: OTM-09 was at PJ+9d and OTM-24 is skipped
- BTM = Backup OTM
  - Contingency, in case OTM is missed, e.g., due to safe mode
  - Roughly PJ+7d, but depends on development, uplink, and execution schedules
- APO = Apojove OTM
  - Required in most 53-day orbits to keep PJ altitude  $\leq 8000$  km, and alter orbit plane (including inclination) to avoid eclipses – APO plan may change (due to tradeoff among  $\Delta V$ , ops schedule, and maneuver delivery statistics)
  - Roughly Apojove-4d, but depends on development, uplink, and execution schedules
- BPO = Backup APO
  - Contingency, in case APO is missed
  - Roughly Apojove+3d, but depends on development, uplink, and execution schedules
- STM = Statistical Trim Maneuver
  - Planned for most but not all orbits due to long mapping time between OTM and next PJ (may be canceled if post-OTM or -APO trajectory prediction for next PJ is acceptable)
  - Roughly PJ-14d, but depends on development, uplink, and execution schedules

# Eclipse geometry (from Nav)



In our trajectory with  
53-day orbits, Nav uses  
apojove maneuvers to change  
the orbit and avoid eclipses  
prior to PJ22 and PJ23  
(September-November 2019)

# Eclipse avoidance strategy

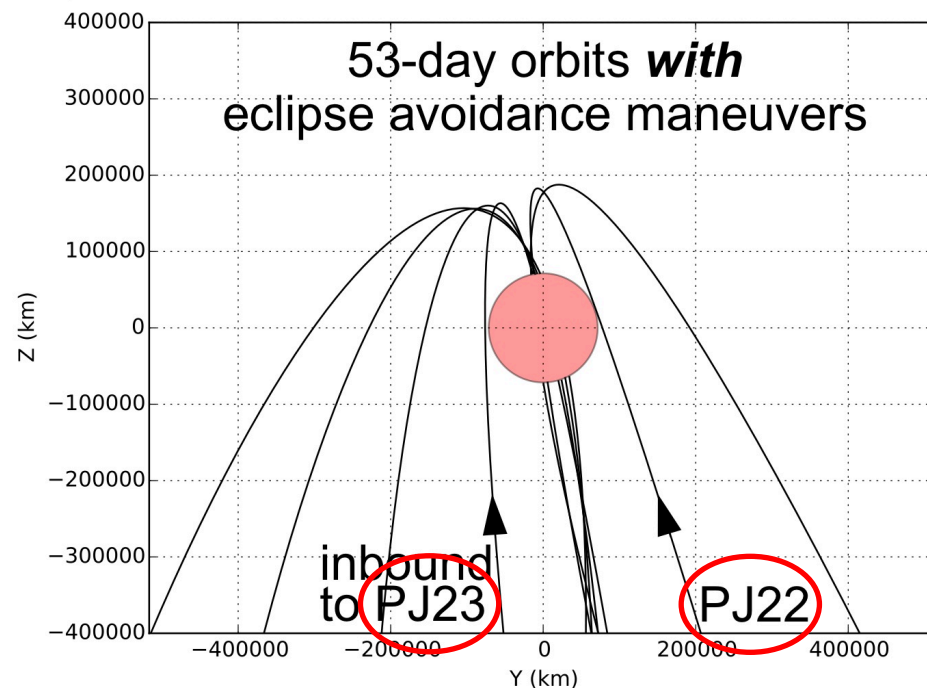
- Best viewed in PowerPoint slide show mode (click on animation right-arrow buttons):

Sun-Jupiter rotating frame, viewed from behind Jupiter directly towards Sun,  
around time of eclipse season

Juno view towards Jupiter (North up)

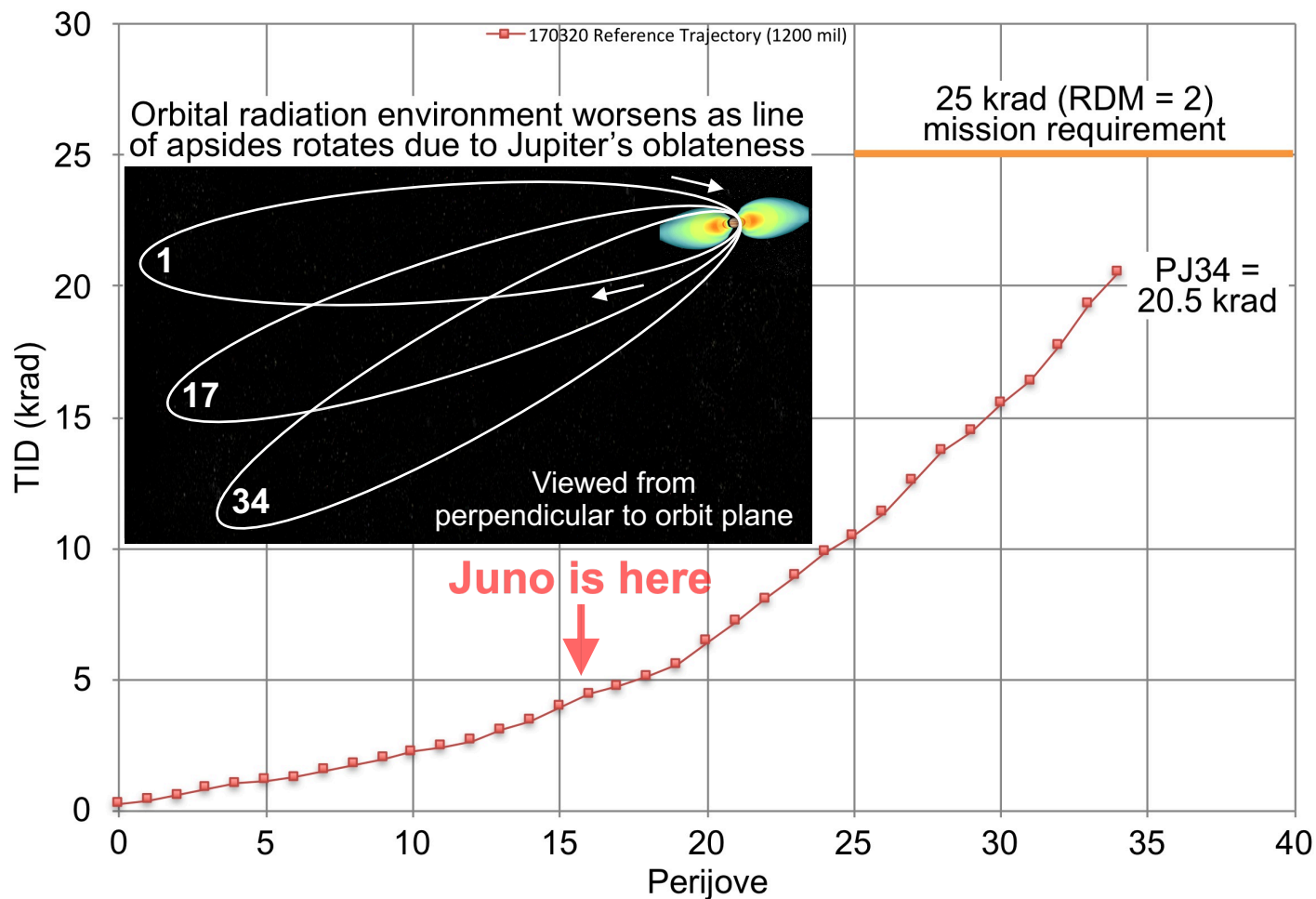


Inbound to PJ23 (near equator crossing)



# Radiation accumulation vs. perijove (from Nav), and orbital radiation environment

- Predicted radiation accumulation (TID = total ionizing dose):



- View in slide show mode to see radiation belts wobbling with Jupiter magnetic field